GULF RESEARCH REPORTS

Volume 4, Number 2

Published by the

GULF COAST RESEARCH LABORATORY
Ocean Springs, Mississippi

November 1973

Gulf Research Reports

Volume 4 | Issue 2

January 1973

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DOI: 10.18785/grr.0402.01

A QUARTER CENTURY OF GEOLOGY AT THE GULF COAST RESEARCH LABORATORY (1948–1973)

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After its founding at the Mississippi Academy of Sciences meeting on May 3, 1947 in the Buena Vista Hotel, Biloxi, Mississippi, the Laboratory offered two biological courses during its first summer session but no geology. Geology has been an integral part of Gulf Coast Research Laboratory since its second year of existence. During the first few years the abandoned Civilian Conservation Corps camp in Magnolia State Park, east of Ocean Springs, was used for housing the Laboratory. The activity was directed by Dr. R. L. Caylor, Chairman of the Science Division, Delta State Teachers College in Cleveland, Mississippi. An assortment of temporary buildings served as residence, office, library and dining hall. From surplus army equipment additional dormitory buildings were constructed and vessels of the Mississippi Sea Food Commission were borrowed at Ocean Springs Harbor for field work. The Mississippi Board of Trustees of Institutions of Higher Learning was induced to assume responsibility for the Laboratory and the State Legislature established it as a state institution in 1948 and appropriated ten thousand dollars for its operation in 1948–50.

Doctor Caylor served for several years as director of the Laboratory. He was only on the grounds permanently during the summer. He invited Dr. Richard R. Priddy, Chairman of Geology at Millsaps College in Jackson (1948–1972) to help develop a geology teaching program and join the Executive Board of the Laboratory. Priddy's participation had a profoundly beneficial effect on the geological work for years to come. With youthful enthusiasm and interest in his subject he gradually overcame the problems created by the lack of equipment, primitive, inconvenient facilities and his initial unfamiliarity with coastal geology. Makeshift instruments (sediment corers, oxygen and pH-meters, etc.) had to be manufactured. In the coming decades practically all Millsaps geology majors and several chemistry majors attended geology courses offered during the summers. These courses, in fact, were made a recommended summer field camp substitute for the Millsaps geology majors.

While in 1947 only botany and marine biology were taught, in August of 1948 geology became the third established course and a two-week marine sedimentation problems class was taught by Priddy with the assistance of C. P. Marion, a graduate student at Mississippi

State College. Between 1949 and 1955 the course was called Marine Sedimentation. After 1948 all geology courses lasted three weeks and carried three hours credit. The four students in 1948 (C. A. Barton, E. R. Campbell, F. G. Clark and W. E. Cook) were all from Millsaps and students from this college were always very well represented in the geology classes of the following summers (Table 1).

In the early years sediment sampling from the Biloxi Bay bottoms and the surrounding beaches occupied the course, along with the description and grain size analysis of the samples. Later the class projects became more varied and carried students to many different locations along the Mississippi shore. Marion taught the geology course during the summers of 1949–50. In 1952 Arthur T. Allen of Emory University was the instructor and during the following three summers Dr. Olin T. Brown of Mississippi Southern College (later University of Southern Mississippi) taught the course. Priddy taught in 1951 and again from 1955–58. In those formative years all professors practically donated their efforts and time. In the beginning the teaching and research work at the Laboratory was largely restricted to the summer months. As late as 1954 the year-round staff consisted of three part-time clerical and maintenance personnel and only two full-time scientific staff members, including Dr. A. E. Hopkins, the director who had become the first full-time director in 1952. It was not until 1961 that the first full-time geologist assumed his duties.

The physical expansion of the Laboratory and its geological facilities proceeded slowly but steadily. With the help of the Executive Secretary of the Board of Trustees of Institutions of Higher Learning, the Laboratory acquired the Smart property on Davis Bayou, a mile and a half south of the facilities in Magnolia Park. The purchase price was $35,000. A 2½-story main building (Fig. 1) that became known as the "Big House," was a former summer home that had been constructed in 1900. The surrounding 49 acres of land was a beautiful setting on a small peninsula bounded by Halstead, Stark and Davis bayous. In 1950, the "Big House" was occupied by Laboratory personnel and a fire in the Magnolia Park facilities during August of that year hastened the completion of the move to the Smart property in 1951.

One of the auxiliary structures behind the site of the future Hopkins Building, by the boat harbor, became the "mud shack", a one-room geological classroom-laboratory building. This had been a former servant's quarters. Between 1961 and 1965 the small kitchen and pantry of the "Big House" were used for the geology office and storage room. With the exception of two wooden dormitories, Laboratory buildings were clustered on low ground along Davis Bayou. The dormitories were reassembled on the slopes of the "Hill", the densely wooded, flat-topped "hinterland" which formed the center of the small

Table 1.

Attendance of Summer Geology Classes at Gulf Coast Research Laboratory 1948–72

	1948-52	1953-57		1958-62		1963-67		1968-72		TOTAL 1948-72	
College of Origin	*1	1	*2	1	2	1	2	1	2	1	2
Millsaps College	22	20	8	8	10	16	16	20	20	86	54
Mississippi State U. (Mississippi State Col.)	5	4	2	9	8	3	2	2	0	23	12
U. of Southern Mississippi (Mississippi Southern Col.)	4	39	1	1	0	5	6	4	3	53	10
U. of Mississippi	0	0	0	4	3	0	0	4	3	8	6
Other (*from 11 states)	2	3	1	6	8	5	7	9	15	25	31
TOTAL	33	66	12	28	29	29	31	39	41	195	113

*1. "Marine Sedimentation" - "Marine Geology" - "Physical Marine Geology" courses.
*2. "Problems in Sedimentation" - "Chemical Marine Geology" courses.
*Other teaching institutions represented by students were located in Alabama, Florida, Georgia, Illinois, Louisiana, Missouri, New York, Ohio, Pennsylvania, Tennessee and Texas,

Figure 1. The "Big House" shrouded by live oaks, from the pier. The building was demolished by the 1969 hurricane and a parking lot covers its site. (Photo by J. O. Snowden)

peninsula at 15–18 feet elevation and provided the potential for the further expansion of the Laboratory.

In addition to sediment studies in the Biloxi Bay area the study of water and sediment chemistry of the bays and bayous became an important subject during the summer sessions. Priddy in 1952 involved Dr. Franklin W. James of the Millsaps Chemistry Department in the study of Fe, Si, Ca, Mg, nitrate, nitrite, sulfate, sulfide, organic carbon and other components of the coastal waters and sediments. Priddy likewise involved Dr. Joseph B. Price, Chairman of the Millsaps Chemistry Department, in this study from 1954 until his untimely death in 1963. Salinity, redox-potential, pH, chlorinity and other characteristics were studied in some detail. A few Millsaps chemistry majors also took part in this study, including J. D. Powell and Hugh Burford. Numerous abstracted progress reports and papers originated from these investigations. Two of the papers, by Priddy and Price, dealt with colorimetric and rapid volumetric analysis methods of brackish waters and an issue of the Mississippi Geological Survey Bulletin contained the summary of the analytical results of the Mississippi Sound work. As a result of this emphasis on water and sediment chemistry, two geology courses were offered, starting in 1956. "Marine Geology" (later renamed "Physical Marine Geology") dealt with physical geological and sedimentological aspects of coastal

Figure 2. Dr. Joseph B. Price, Chemistry Chairman and A. D. Bishop, 1960 summer student (both of Millsaps) in the old Hopkins Building. (Photo by J. O. Snowden)

Figure 3. Professor R. R. Priddy in the Hopkins Building (before Hurricane Camille). (Photo by Dr. J. O. Snowden)

geology, while "Marine Sedimentation" (later renamed "Problems in Sedimentation", and still later as "Chemical Marine Geology") concerned itself with the analysis of chemical components and of the physico-chemical properties of bottom sediments and of the coastal water bodies. Until Dr. J. O. Snowden, Jr., one of Priddy's former students and a member of his Millsaps faculty at the time, took over the teaching of the chemical marine geology course in 1968, Priddy taught it every summer with the exception of 1959. The Laboratory hosted regional geology courses for college instructors during the consecutive summers of 1965–68. These National Science Foundation-sponsored courses were directed by Priddy in the Caylor Building.

Physical facilities were slowly improving. Since its completion in June 1951, the geology classes were able to utilize parts of the small (30 by 60 feet) Caylor Building, the first brick structure on the campus. After the arrival of Dr. Gordon Gunter in 1955 to be director of the Laboratory, a second one-story classroom-laboratory building, named after A. E. Hopkins, was opened in 1956 and all of the Caylor Building along with parts of the Hopkins Building were used for geological purposes. Both these structures and the "Big House" were demolished in the 1969 hurricane and only the Hopkins Building was rebuilt thereafter. By this time, however, geology work had for several years been occupying modern, well-equipped, air-conditioned

Figure 4. The old, un-air-conditioned Hopkins Building before Hurricane Camille. (Photo by J. O. Snowden)

quarters in the Oceanography Building on the top of the "Hill" which, when completed in May 1965, became the center of the Laboratory complex.

In 1959 both geology courses were taught by Dr. A. R. Cariani of University of Mississippi. The following year when the Laboratory still had only six resident scientists, including Doctor Gunter, Dr. David A. DeVries of Mississippi Southern College taught Physical Marine Geology. He became resident geologist in 1961 and taught the course as a member of the staff through the summer of 1966. Between the summer of 1967 and January 1971, this position was filled by W. L. Siler.

Student class reports written under the supervision of DeVries and Priddy indicate a variety of study projects during the summers. Modern beach sands were investigated on Horn, Ship and Round Islands and on Belle Fontaine Beach; ancient beach sands were studied at Belle Fontaine, changes of the Marsh Point sand spit were measured and recorded in great detail and minor and major beach forms investigated in several areas. One of the most original projects was jet-drilling with a centrifugal pump from a boat in Davis Bayou in estab-

Figure 5. 1960 Chemical Marine Geology class at the Laboratory. Front row, left-to-right: Fred Lockett, Martin Hobbs and Dr. R. R. Priddy. Back row: Frank Brooks, Joe Snowden, Al Bishop, Dr. J. B. Price and Billy Moore.

lishing the configuration of an incised Late Pleistocene stream valley in the continuation of the present Stark Bayou. This gully was filled in and buried by Holocene deposits. Some of the heavy mineral, microfauna and other studies which were initiated during the summer sessions developed into masters theses and several abstracts and papers were published later. Similar abstracts resulted from the chemical studies of Priddy and his associates on the sulfur cycle, flocculent materials, Eh–pH conditions, humus content and other aspects of the bottom muds and the waters of Mississippi Sound and adjacent bays and bayous.

Doctor Snowden of Louisiana State University in New Orleans and the writer (who became affiliated with the Laboratory on a part-time basis on July 1, 1970 and became Geology Section Head June 1, 1971) have undertaken an extensive study of the chemistry and sedimentary petrology of the deposits, the chemistry and the pore-water and overlying free-water bodies along the entire Mississippi coast with a grant from the Water Resources Institute under the U. S. Office of Water Resources Research. The Pearl, Wolf and Pascagoula river estuaries and Davis, Heron, Old Fort and Graveline bayous were investigated in this respect during 1970–72. Instead of the time-consuming classical titrimetric methods, atomic absorption spectrometry was employed and the salinity of the squeezed-out pore water measured by the micro-resistivity method. The sulfate, nitrite and nitrate content of the water samples was determined by the fast turbidimetric analysis. These new methods were introduced in Dr. J. O. Snowden's course in which water chemistry and the chemical interaction between interstitial pore water and the enclosing sediments has been emphasized.

As the result of Doctor Gunter's vigorous program of development and expansion of the Laboratory, several large modern buildings were added in 1965–71. Recovery was fast from the severe devastation of Hurricane Camille in August 1969 with generous federal, state and private aid. The Instructional Facility and Oceanography Buildings became the largest on the campus, both with approximately 18,000 square feet gross area. A physical marine geology and a chemical marine geology classroom with adjoining office and storage rooms opened in the two-story Instructional Facility Building in 1971 (renamed Richard L. Caylor Building in 1973) and additional space was utilized for geological research and sample storage in the new Research Facility Building the same year. A new exhibition center near Point Cadet, Biloxi, prompted planning of part of the future exhibit to demonstrate the geological makeup and history of the coast and the role environmental geology plays in the area.

Geology has also acquired additional personnel. In 1971 Michael Bograd and Edmond Funel worked as temporary assistants in the sedimentation laboratory and the field. The following year two per-

Figure 6. Chemical Marine Geology class (August, 1962) at Horn Island. W. E. Davenport, Ethel Radzewicz (Millsaps) Marshall Kern (Mississippi Geol. Survey), L. D. Simpson (Mississippi State) and W. H. Allen (University of Mississippi). Dr. R. R. Priddy at right. (Photo by Marion Saucier)

manent assistants replaced them: Wade Howat, assistant geologist (B.S. 1971), and Joseph Milner. In 1972 Robin Wink replaced Milner as geo-technician and Mrs. Kathy Peter (B.S. 1972) also stepped in as temporary sedimentation laboratory assistant. These developments paved the way for an expanded geology program. In 1971 geology participated in an interdisciplinary project of earth resources data collection from southeastern, coastal and offshore Mississippi, relevant to the cultural, physical and economic development of the State of Mississippi. This project, which resulted in a geological bibliography and survey of the map coverage of the subject area, was done in conjunction with geology faculty members at Mississippi State University and the University of Southern Mississippi for the Earth Resources Laboratory, Mississippi Test Facility (Bay St. Louis) of the National Aeronautics and Space Administration. Since 1971 the Geology Section has also participated in another complex research project, involving the three state universities in Mississippi under the Office of Sea Grant Programs, in studying sedimentation and sediment chemistry in a St. Louis Bay oyster reef and in the Bay area in general. Another study, in cooperation with the Fisheries Section, deals with the sedimentology of Biloxi Bay and is done for the Earth

Resources Laboratory, NASA. The writer was appointed by Doctor Gunter in September 1971 to represent the Laboratory on the Universities Marine Center Marine Education Committee for Mississippi.

Since 1972 the Section has actively participated in the Environmental Affairs Committee of the Laboratory. Work of this committee has included formulating recommendations for the Mississippi Marine Resources Council about proposed construction projects in the coastal zone which could have an impact on the coastal environment in Mississippi. The head of the Section also participates in the workings of the Point Cadet Science Advisory Committee which assists in the development of the Laboratory's new exhibition-research facility, the Marine Education Center, in the southeastern corner of Biloxi. As of 1973 the author has also been charged by Director Harold D. Howse to represent the Laboratory in the recently established Mississippi Mineral Resources Institute.

Systematic acquisition of topographical, hydrological, geological and aerial photo maps has been started for a geological map collection for research and teaching purposes. The collection primarily consists of maps related to Gulf and Atlantic coastal areas but also includes archive copies of Mississippi-Louisiana area charts. Holdings of the library in geological and related fields have been steadily increasing and the library currently is subscribing to about twenty domestic and foreign periodicals, dealing with different aspects of earth sciences. During the past decade, as demands have periodically arisen, staff geologists have taught physical geology evening classes at the University of Southern Mississippi Keesler Air Force Base Resident Center in Biloxi and on Gulf Park Campus, Long Beach. Recently, historical and environmental geology courses were taught by the writer.

Starting in 1971 one of the main research objectives of the Geology Section has been the detailed study of the composition and geological history of the Pliocene Citronelle Formation, the Pleistocene fluvial-alluvial, brackish and nearshore-marine deposits and of the Holocene-Recent sediments, including the relationship of these units to each other and the surface configurations of the Miocene "basement" unit. The problem of the older (pre-Sangamon), higher Pleistocene marine deposits, barrier beach ridges was investigated not only in the Mississippi Coast but also in adjoining states and the coastal Florida Panhandle. Correlation problems of the Citronelle under the present Pleistocene coastal plains and its distinction from underlying Miocene and overlying Pleistocene formations are among the several problems, as is the nature and origin of "terraces" and scarps in the coastal zone. The Late Pleistocene (Sangamon) Waveland-Gulfport-Belle Fontaine mainland barrier ridge system is now being investigated in great detail. Other field studies revealed that there is no geological proof for the existence of earlier Pleistocene, higher coastal

Figure 7. Physical Marine Geology class in the Sedimentation Laboratory, Oceanography Building, 1971. Mary Whitten (left) and Norma Weaver, University of Mississippi students with author. (Photo by Catherine Campbell)

ridges, previously widely reported from several areas of the northeastern Gulf coastal region.

An extensive core-drilling program, so essential in coastal regions with few natural outcrops, was initiated in October 1971 to solve the numerous stratigraphic-geomorphological problems. The most important result of this project to date has been the recognition of a widespread, continuous, shallow stratigraphic unit under the Sangamon-age barrier ridge zone and under certain areas of the Late Pleistocene coastwise alluvial plain. This fossiliferous unit (named Biloxi Formation) appears to represent the marine transgression phase of the Sangamon Interglacial and is correlative probably along the whole northern coast of the Gulf of Mexico. Plans also call for stratigraphic exploration drilling in Mississippi Sound and on the offshore barrier islands in order to learn more about the pre-Pleistocene, Pleistocene and Holocene history of the north-central Gulf coastal-nearshore area and its relationship with the subsiding zone of the Mississippi River Delta region.

Geological field work including future detailed boring in Mississippi offshore barrier islands and the south Hancock County marsh-beach ridge complex should clarify the Holocene history of the present

offshore-inshore area and the changes (erosional destruction, island migration, accretion) which profoundly affect them. Long-range effects of natural (hurricanes) and man-made changes on these features and the resulting effects on the mainland coast and the Mississippi Sound are not yet adequately known. Such geological studies would contribute not only to the understanding of the formation and destruction of barrier islands and mainland barrier beaches during the Late Quaternary in general, but also to the clarification and possible solution of serious environmental problems along the Mississippi Coast.

Results of geological research of the past few years were demonstrated in May 1973 during a two-day field trip of the New Orleans Geological Society. The trip covered a wide area between New Orleans East and Dauphin Island, Alabama. A guidebook published for the occasion summarized the present knowledge about the Miocene-Recent coastal formations and the presently active geological processes. At the request of the Commission on Shorelines of the International Association for Quaternary Research, we are also collaborating in supplying regional information for the preparation of a set of world shoreline maps, covering the Late Pleistocene, Late Holocene and Recent shore positions.

ACKNOWLEDGEMENTS

Dr. Gordon Gunter, Director Emeritus and Professor of Zoology at the Laboratory, encouraged the writing of this account and reviewed the manuscript. Doctor Gunter and Doctor Snowden supplied data used by the author as did Doctor Priddy, whose mimeographed descriptions of the geological activities at Gulf Coast Research Laboratory were invaluable in the preparation of this article. Michael Bograd greatly assisted in the tabulation of the student attendance data.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

The Occurrence of the Remarkable Scyphozoan, *Deepstaria enigmatica*, in the Gulf of Mexico and Some Observations on Cnidarian Symbionts

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DOI: 10.18785/grr.0402.02

Recommended Citation

Phillips, P. J. 1973. The Occurrence of the Remarkable Scyphozoan, *Deepstaria enigmatica*, in the Gulf of Mexico and Some Observations on Cnidarian Symbionts. Gulf Research Reports 4 (2): 166-168.
Retrieved from http://aquila.usm.edu/gcr/vol4/iss2/2

THE OCCURRENCE OF THE REMARKABLE SCYPHOZOAN, *Deepstaria enigmatica*, IN THE GULF OF MEXICO AND SOME OBSERVATIONS ON CNIDARIAN SYMBIONTS

by

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On 8 July 1965 one damaged specimen of the remarkable scyphozoan, *Deepstaria enigmatica* Russell 1967, was taken in the course of a sampling program conducted by the Department of Oceanography, Texas A&M University in a ten-foot Issacs-Kidd midwater trawl in the Yucatan Basin. The trawl was put into water at Lat. 19° 58′ N, Long. 85° 14′ W. This is the first report of *Deepstaria* in the Atlantic region. This medusa is otherwise known only from the Pacific Ocean where it has been captured by slurp gun from the submersible *Deepstar* over the San Diego Trench and has been taken in midwater trawls by the Scripps Institution of Oceanography Mid-Pacific Expedition (Barham and Pickwell 1969 and Russell 1967).

The present specimen, although badly torn, is clearly recognizable as *D. enigmatica*. The anastomosing canal lattice has the characteristic pattern described by Russell. The medusa is a deep purple-blue in color and appears to have had a diameter in excess of 70 cm. The mesogloea is 18 mm. thick near the center of the disc. Oral arms are not discernible and portions of the disc are considerably distorted by local extreme contraction. Fragments of female gonadal material are attached to parts of the subumbrellar surface. These gonadal fragments, too small to permit any observations on gross gonad morphology, contain zygotes in various stages of early cleavage. Ova and zygotes are small (c. 100 microns diameter) and have very little, if any, yolk. The depth at which this jellyfish was taken cannot be stated with any certainty since the collecting device fished from the surface to a depth of 2400 m., no "at depth" closing device having been used.

The occurrence of this unique scyphomedusan in the Gulf of Mexico constitutes a considerable range extension. Closer examination of midwater trawl samples from other regions and more extensive sampling will probably lead to the discovery of more specimens of *Deepstaria* from other areas. I strongly suspect that *D. enigmatica* may have a circumglobal distribution in tropical and subtropical waters. As is the case with many oceanic organisms, the zoogeographic dis-

[1] Present address: North Atlantic Division, U.S. Army Corps of Engineers, 90 Church Street, New York, N. Y. 10007.

tribution of *Deepstaria* can probably be correlated with intensity of sampling and workers who can identify it.

Barham and Pickwell discuss a commensal or symbiotic association between the giant parasitic isopod *Anuropus* and *Deepstaria*. Photographs taken by *Deepstar* show one of these isopods clinging to the subumbrellar surface at the time of capture. Barham and Pickwell state that the medusa "did not pulsate or show normal swimming movements. Instead the medusa appeared flaccid and seemed to be floating passively." Russell noted the absence of stomach, epithelial lining and parts of the coronal muscle, and suggested the possibility the medusa was moribund at the time of capture. Taking into account the occurrence of nematocysts in the stomachs of some anuropids (as reported by Menzies and Dow 1958 and cited by Barham and Pickwell) Barham and Pickwell suggested that the isopod feeds on the jellyfish, incapacitates medusa movement and creates a "floating protective environment," which they state is a process that stops "somewhat short of the reduction of salps and pyrosomes into thin-walled houses by the well known amphipod, *Phronima sedenteria*." It should be noted that Barham and Pickwell did not demonstrate nematocysts in the stomach contents of the *Anuropus* in association with *Deepstaria*. While the isopod may be traveling on an atenic host or is actually a true parasite of *Deepstaria* there are no criteria for establishing just what can be considered normal swimming movement for this medusa, if indeed it normally does generate swimming movements. I find it difficult to believe that *Anuropus* incapacitates the medusa since my own personal and published observations (Phillips, Burke and Keener 1969) indicate that medusae can serve as hosts for a wide variety of crustaceans and other metazoans without incapacitation. In actual fact the moribund state will render an organism prey for a wide range of animals which would not normally attack it, as may possibly be the case for *Deepstaria*.

Additionally, it is exceedingly dubious that *Phronima* invades salps or pyrosomes and converts them into thin-walled houses. The structure of the amphipod house bears little semblance of that of any tunicate and the resemblance is a superficial one at best according to Leo Berner, Jr., (personal communication). It is much more likely that a *Phronima* secretes its own domicile. Examination of *Phronima* houses evinces no evidence of zooids of any type ever having been embedded in the gelatinous matrix. There is also a very striking correlation between house proportions and amphipod size, a situation that would not be so well defined if the *Phronima* did not secrete it.

Symbiotic relationships between Scyphozoa and other metazoans are very common. Pickwell and Barham cite seven such relationships and their list can be considerably lengthened. Fish-jellyfish associations are probably the best known (Mansueti 1963 and Phillips, Burke and Keener 1969) and many are known that involve Crustacea and

medusae (Gutsell 1928 and Phillips, Burke and Keener 1969). It should be noted that there are trematode and cestode parasites of medusae (Dollfus 1931 and Stunkard 1969) as well as vermiform parasites of unknown phyletic affinities which are commonly found in some rhizostomes (Moestafa and McConnaughey 1966 and Phillips and Levin, in prep.). I have also found on very rare occasions hyperiid amphipods embedded in the mesogloea of two species of calycophoran siphonophores (*Diphyes dispar* and *Chelophyes appendiculata*). Metazoan parasites or symbionts of Cnidaria are not at all rare; they are merely seldom looked for and even less seldom investigated.

It remains to be seen whether or not life cycle completion in *Anuropus* is dependent on cnidarian hosts. Data presented by Barham and Pickwell regarding the association between *Anuropus* and *Deepstaria* are insufficient for drawing conclusions.

ACKNOWLEDGEMENTS

I would like to thank Dr. Leo Berner, Jr. (Department of Oceanography, Texas A&M University) and Dr. Sewell H. Hopkins (Department of Biology, Texas A&M University) for critical review of the manuscript. This study was supported in part by NSF Grant GP 3555. The Gulf of Mexico *Deepstaria enigmatica* specimen was made available to me through the courtesy of Dr. W. E. Pequenat and Dr. L. Berner, Jr. and has been placed in the U. S. National Museum, Washington, D. C., U.S.A. This paper in modified form was part of a dissertation submitted in partial fulfillment of the requirements for the Ph.D. degree in biology at Texas A&M University.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

Stranding Records of a Finback Whale, *Balaenoptera physalus*, from Mississippi and the Goose-Beaked Whale, *Ziphius cavirostris*, from Louisiana

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DOI: 10.18785/grr.0402.03

Recommended Citation

Gunter, G. and J. Christmas. 1973. Stranding Records of a Finback Whale, *Balaenoptera physalus*, from Mississippi and the Goose-Beaked Whale, *Ziphius cavirostris*, from Louisiana. Gulf Research Reports 4 (2): 169-173.
Retrieved from http://aquila.usm.edu/gcr/vol4/iss2/3

STRANDING RECORDS OF A FINBACK WHALE, *Balaenoptera physalus*, FROM MISSISSIPPI AND THE GOOSE-BEAKED WHALE, *Ziphius cavirostris*, FROM LOUISIANA

by

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INTRODUCTION

Stranding records are sometimes the only source of data concerning some species of cetaceans and it is appropriate that these incidents be reported in some detail. This is particularly true of rare or little known species. Bottle-nosed dolphin (*Tursiops truncatus*) carcasses stranded on the Mississippi and Louisiana coasts are so common that they receive little attention. Other species occur and have, no doubt, been overlooked or confused by laymen with *Tursiops*. Even the rare stranding of large whales in this area may go unreported except for news stories that fail to identify the animal properly and which are not readily available to cetologists.

The stranding in 1967 of one of the first definitely reported finbacks, *Balaenoptera physalus*, in the Gulf of Mexico is given here. It is the first Mississippi record.

Moore (1953) noted that "only six specimens of the goose-beaked whale have been reported on the eastern coast of North America" and provided four new records from the Florida west coast. The present report includes a Louisiana stranding in 1969.

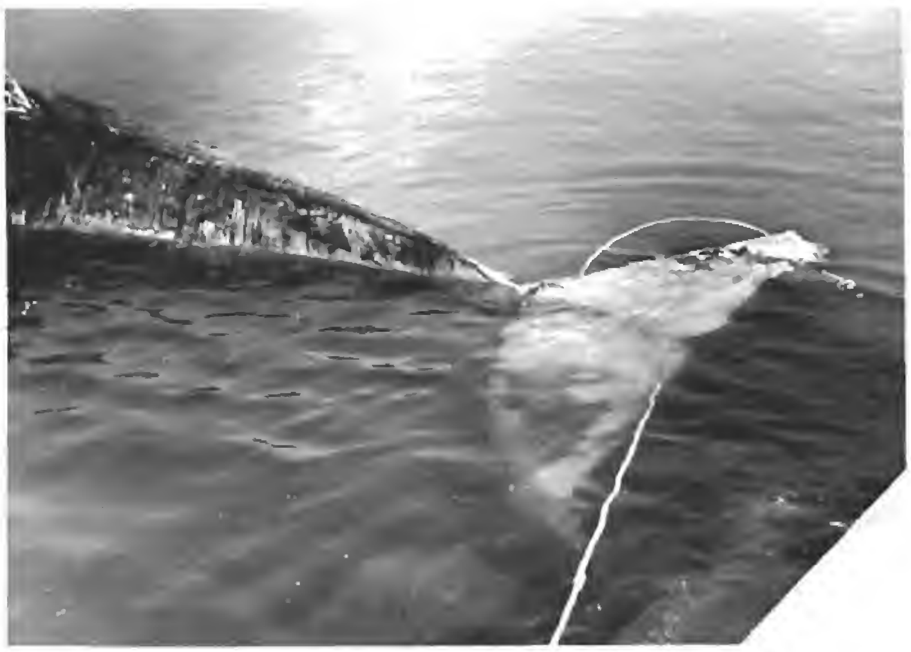
SPECIES ACCOUNT

Balaenoptera physalus

The Gulfport Ship Channel extends from the western end of Ship Island, a barrier island off the Mississippi coast, northward across Mississippi Sound for 11.5 nautical miles to the Gulfport Harbor. It has a limiting depth of 40 feet. On 7 April 1967 a baleen whale invaded Mississippi Sound by the ship channel for the first time that this event has ever been reported. This is also probably the first time a whale has entered the bay during the past several hundred years because the waters were too shallow until the ship channel was dug.

The general events have been described by Heiliger (1967) as follows: On the late afternoon of April 7, Captain Peter Skrmetta and Peter B. Lasanen were returning on the Pan-American Clipper, an excursion boat which operates between Gulfport and Ship Island, when they saw a whale spouting near the mouth of the Gulfport Har-

Plate I. Ventral views of belly (a) and tail (b) of a stranded finback whale at Ship Island, Mississippi taken 11 April 1967.



bor. Needless to say, this was most surprising. The next day this whale was found to have run ashore and died inside of Ship Island. It was later towed closer to Fort Massachusetts, the landing point on the island, as an attraction to tourists and excursionists aboard the Pan-American Clipper. This attraction lasted until the odor of the decaying animal became overwhelming, when Captain Skrmetta moved the carcass to the Gulf beach and partially buried it with the help of a dragline dredge mounted on a barge.

A group from the Gulf Coast Research Laboratory, including the senior author, visited Ship Island on April 11 and inspected this whale by going around it in a skiff. Heiliger (1967) had previously estimated the length as 45 feet and the weight at about 12 tons. The animal was a maturing male with a protuberant penis well over a meter long. There was a good bit of blotchy white on the right side of the anterior belly and the lower side of the flukes was white. The inner flippers were also white. Some of this can be seen in the two ventral view photographs (Plate I, a & b). These and all other aspects of the specimen corresponded to the finback whale, *Balaenoptera physalus*.

After this whale had been buried for a few months its head was dug up and exhibited at Fort Massachusetts for the delectation of the excursionists to Ship Island. The actions of thieves and the Hurricane Camille on August 17–18, 1969 have reduced the skull (25 June 1972) to a remnant of one jawbone.

Records of *Balaenoptera* sp. from Louisiana have been summarized by Lowery (1943). The Louisiana State University Museum had a piece of baleen from a probably Louisiana or Mississippi specimen of *B. physalus* taken about 1928. Several more probable and a couple of definite records from Louisiana will be summarized by Lowery (in press).

Ziphius cavirostris

We first received the report of a whale stranded on the Chandeleur Islands of Louisiana from Mr. Bob Stevens who saw it on a routine inspection flight of the Gulf Islands National Wildlife Refuge in April 1969. The carcass was located later on 15 May 1969 by J. Y. Christmas, Tom McIlwain and Lionel Eleuterius. It was partially buried in the berm about five miles south of Chandeleur Lighthouse on the Gulf beach (approx. lat. 29° 58′ N. long. 88° 49′ W.). Heavy surf prevented landing on the Gulf beach, but Captain Kenneth Melvin was able to put the party ashore from Chandeleur Sound, across the island.

The skin had sloughed off the carcass so that muscle tissue was exposed on some areas of the body. It lay on the right side with dorsal fin and flukes buried. The beak was about half buried with jaws open at 10–15°. The whole body was blackened so that natural color could

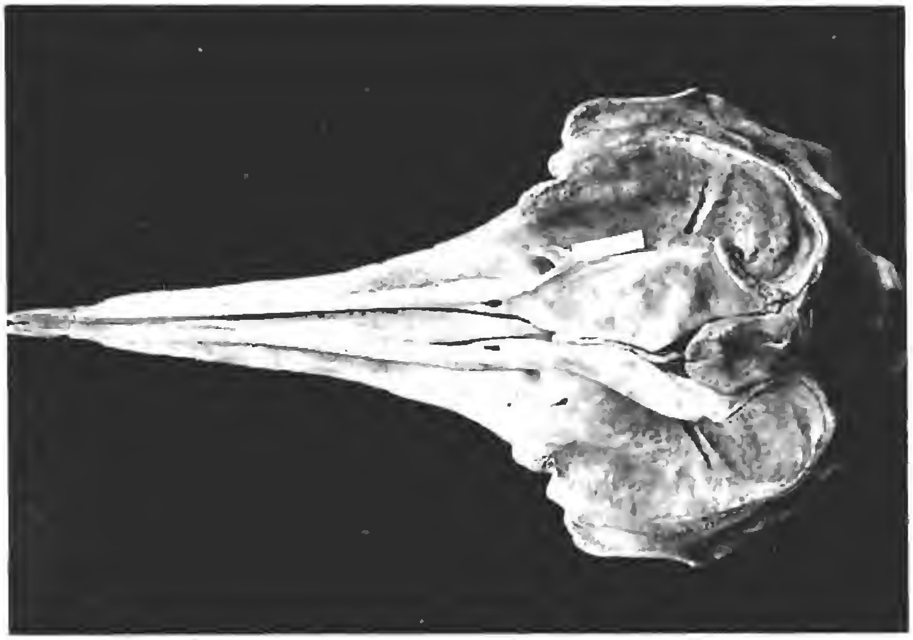
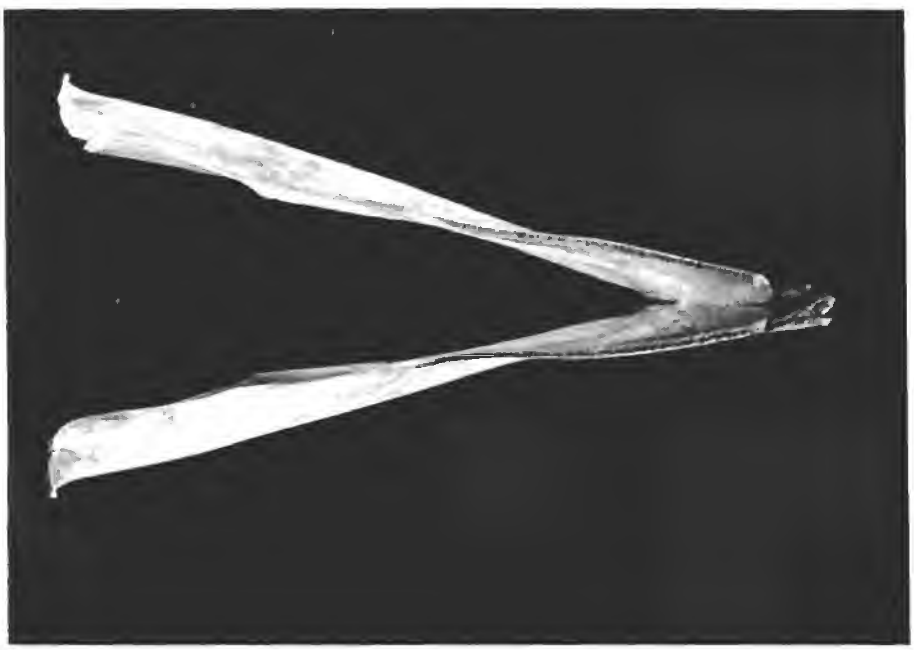


Plate II. Upper view of skull (a) and mandibles (b) of a specimen of the goose-beaked whale found on the Chandeleur Islands, Louisiana in April 1969. Courtesy of Dr. G. H. Lowery, Jr.



not be ascertained. The viscera were pushed into the mouth and an area about 46 cm in diameter around the anus was distended.

When dug out, the dorsal fin and flukes were essentially intact but their shape was not clearly discernible. Teeth could not be seen. Somewhat crude measurements made with a meter stick were as follows:

Total length—559 cm. (18.1 ft.)
Maximum body depth—106 cm.
Tip of beak to dorsal base—336 cm.
Tip of beak to eye—71 cm.
Tip of beak to pectoral base—132 cm.
Lower jaw length—38 cm.
Upper jaw length—35.6 cm.
Flukes, Maximum width—112 cm.
Blowhole (located behind eye)—7.6 cm.

The carcass was left intact because any parts that could have been removed could not be carried across the island to the boat.

About a month later, J. Y. Christmas and Richard Waller returned and landed on the Gulf beach. Decomposition was considerably advanced. The head, tail and left pectoral were removed, placed on a sheet of polyethylene and dragged into the water. A piece of nylon webbing was secured around the whole bundle and it was lifted to the trawl deck of the boat. The return trip stank.

At the Gulf Coast Research Laboratory the bundle was buried above normal tides. A few days after Hurricane Camille had inundated the whole area we found that only shallow erosion had occurred at the burial site, exposing the end of the beak. One tooth was found on the ground. The head was still putrid. It was covered and not disturbed again until Dr. George H. Lowery, Jr. removed the material to Louisiana State University for museum preparation.

He has kindly furnished photographs of the cleaned specimen which is now LSUMZ15609. Plate II is an upper view of the skull (a) and the mandibles (b) of this specimen. Doctor Lowery (personal communication) was able to confirm our tentative identification as *Ziphius cavirostris*. He later carried photographs to London where F. C. Fraser at the British Museum concurred in this identification.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

Some Effects of Hurricanes on the Terrestrial Biota, With Special Reference to Camille (Reprint)

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DOI: 10.18785/grr.0402.04

SOME EFFECTS OF HURRICANES ON THE TERRESTRIAL BIOTA, WITH SPECIAL REFERENCE TO CAMILLE[1]

by

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INTRODUCTION

There have been very few articles concerning the effects of hurricanes upôn marine and shore organisms. Some effects on fishes have been described by Hubbs (1962) and in that paper he reviewed some of the previous references.

Information on animals killed or injured by hurricanes is scarce because potential observers in areas where they strike are generally more concerned with practical personal matters than biological studies right after a bad storm. The senior author has been in or very close to seven West India hurricanes as they came ashore. Each time he was somewhat forewarned and had determined to make some type of quantitative appraisal of killed animals following these storms. However, on no occasion has this been done. Nevertheless, the two writers have collected some fragmentary information worth recording.

Some Damages to the Fauna on the Mississippi Coast
Hurricane Betsy—9-10 September 1965

When Betsy passed the Mississippi Coast on its way to devastating areas of New Orleans, the center was approximately 50 miles south of Horn Island. Thus the wind blew more or less from east to west along the Ocean Springs–Pascagoula coastal area. Following this storm hundreds of sea balls mostly of the marsh grass *Spartina* were found on the mainland beach of Mississippi Sound near Gulfport.

The water rose to a height of about six feet on the Laboratory grounds and left a strand of debris along the beach. In areas where there was marsh grass, thousands of little drowned mice, the Eastern Harvest Mouse, *Reithrodontomys humulis*, lined the shore in a little brown windrow which was sometimes 100 yards long without a break. Also lying on the beach every ten yards or so was a dead raccoon, *Procyon lotor*. There were so many on the Laboratory grounds that they

[1] This is a *verbatim* reprinting of the paper with the same title published in Volume 3, Number 2 of this journal, which was so improperly laid out that reprints with the plates could not be made and the legends were missing.

had to be hauled away. Raccoons are good swimmers and they certainly did not come from the surrounding nearby marsh-land. Horn Island, which lies eight miles offshore, was either completely or nearly submerged during this storm. The most reasonable assumption is that these coons were drowned in Mississippi Sound, after being washed off of Horn Island and their bodies were finally blown onto the mainland shore.

Hurricane Camille—17-18 August 1969

This has been publicized variously as the worst storm that ever struck North America, or as the worst that has come ashore in this country in 143 years. Old, indefinite accounts indicate that something like this struck Florida in the 1700s. It is quite certain that Camille was the most powerful hurricane that has struck a well-populated shore of the United States. The weather planes flying through it clocked the winds at 218 mph and recorded the lowest natural barometric pressure that has ever been read (26.01 inches).

The "Big House," an old landmark of the Laboratory and of the coast, was splintered and even the brick pillars upon which it stood were washed away.

We have no way of quantifying the destruction of animals, except to say that the clean-up agency, the 43rd Battalion, Corps of Engineers, U. S. Army, reported removing 28 tons of animals from the beach between Biloxi and Gulfport on August 22–24. Most of these animals were dogs and cats, but some horses and cattle were mixed in. After the storm many dogs were homeless and many were systematically shot because they were starving.

Following the storm, the writer was waked up by a bird singing lustily just outside his window; this was the only bird seen for about a week. An unknown number of wild animals, birds, dogs and other life including human beings lost their lives in the storm; after about three days, the odor of decaying animals was noticed in the atmosphere and lasted about a week before it gradually went away.

The bird population and the squirrel population virtually disappeared but both came back after a few weeks time, most noticeably the jaybirds and a few gray squirrels (*Sciurus carolinensis*). The birds disappeared again, probably because they could find nothing to eat. This was certainly true of the squirrels and they were reduced to gnawing the bark off of felled water oaks (Gunter and Eleuterius 1971).

When the storm struck, the seeds of various nut trees—chiefly the hickory, black walnut, and thousands of pecans which are planted in this area—were just beginning to mature. Many of these were blown

down and approximately half of the foliage of those remaining was denuded by breakage of the limbs. The same thing was true of oaks and acorns. Additionally, the nuts themselves were beaten off the trees that remained standing. Presumably for that reason the Eastern Gray Squirrel, which was quite common, had not returned in its former numbers by April 1970. Before the storm it was quite common to see as many as eight of these at one time in a relatively small area of trees in the senior author's front yard. After the storm, he saw none for one week and then he saw a lone squirrel. The squirrel population apparently increased in about three weeks to a month after the storm, then declined again. This observation would bear out the supposition that squirrels moving in from other areas could not find sufficient food and moved out again. The same thing apparently was true of the jaybirds.

There was a decided diminution in the number of birds which came to feeder stations during the following winter. For instance, dozens of birds and sometimes a few hundred in one afternoon formerly fed at a home facing the beach just to the side of the Laboratory grounds. The most numerous species, sometimes present in the dozens at a time, was the Savannah Sparrow. During the past winter only three or four have appeared at a time. The owner, before Camille, had to keep watch on the Starlings and jaybirds because they disturbed and ran off the others, but has had no trouble since the storm. General observations show that the Brown Thrashers, the jaybirds and the Cardinals are present in very diminished numbers even today (April 1970).

These facts have been noticed by other people and recorded, especially in The Dixie Guide by Mr. Clayton Rand who has gone through three bad hurricanes at his home in Gulfport. Mr. Rand has mentioned in his paper several times, the last being February and March 1970, that during former hurricanes there were many snakes and frogs everywhere in the area and that the mosquitoes were quite bad. He has remarked three times in his monthly newspaper that there was a great absence of life following Camille, even of the birds.

To the senior writer, however, the most amazing thing has been the disappearance of the ants up until this time (April 1970). The black carpenter ant and the Argentine fire ant and several other smaller species were quite common in his yard. Apparently they all succumbed to the storm, except for a minute yellow species that goes by the name of sugar ant, which has been seen one time. Bread and other foods set out for dogs and cats were formerly covered with ants in a matter of minutes; but, even this long after the storm, they may remain untouched by ants for days. We do not know the extent of destruction of the Argentine fire ant, but locally they are gone.

It is to be expected that termites and termite feeding animals and

possibly woodpeckers would increase greatly in numbers due to the thousands and thousands of felled trees and rotting timber, a good bit of which, after having had the top broken off, is still upright.

Damages to the Flora on the Mississippi Coast

There are very few reports of the effects of hurricanes, typhoons, or cyclones (tornadoes) on coastal vegetation. Sauer (1962) reported the effects of cyclones on the coastal vegetation of a tropical island (Mauritius) in the Indian Ocean. Chamberlain (1959) and the U. S. Department of Agriculture (1960) reported some of the effects of Hurricane Audrey on the vegetation of south Louisiana. Previous hurricanes which struck the Mississippi coast inflicted minor damage to the vegetation; one of the worst of these storms known to the junior author occurred in 1947.

The "eye" or center of Hurricane Camille came ashore in the Pass Christian–Bay St. Louis area and the path was well marked by the effects of the storm on vegetation. The most apparent and obvious effect was the destruction of the trees. In Jackson County most of the trees blown down were oriented with the tops pointing toward the northwest. In Harrison County near Gulfport, the trees became oriented with the tops pointing toward the west-northwest and in the Pass Christian–Bay St. Louis area, they were oriented in an east-west direction, but some tree tops pointed eastward and some pointed to the west and the trees were nearly parallel in alignment (Figs. 1 and 2). The paradoxical alignment was apparently a result of the initial winds from the east, followed after the "eye" passed over the area, by winds from the west. Trees west of Bay St. Louis near Pearl River were oriented with the tops toward the east-northeast and near Slidell, Louisiana, they were down in a northeast direction.

The intensity of winds from Hurricane Camille could be seen in the number of trees felled, the number increasing as the wind velocity increased toward the path of the "eye." In fact, without referring to other data, one could determine the storm's path by observing the east-west direction in which the trees were blown down and by the gradual increase in the numbers of trees destroyed as the center of the path was approached.

Tornadoes or extremely turbulent winds ripped through many areas on the periphery of the hurricane and the paths of their "touch downs" were well documented in the vegetation. In Magnolia State Park, which almost adjoins the Laboratory property, there is one area 50 feet wide and 17 tree lengths long, which the second author attributed to these tornadic gusts.

The junior author conducted two vegetational surveys to compare the intensity of damage to areas on the periphery of Hurricane Ca-

mille with areas nearer the center. In Jackson County, these surveys showed that in one tract, 4% of the trees were blown down and 10% were damaged to the point that survival was in question. The plant community was dominated by *Quercus nigra* (water oak) with *Pinus elliotii* (slash pine), *Carya glabra* (hickory) and *Quercus rubra* (red oak) being the subdominant species. This 40-acre tract in Magnolia State Park was approximately 22 feet above sea level. Destroyed trees in decreasing order were: red oak, slash pine, water oak, and hickory. It was noted that the heart wood (xylem) of the red oaks had been weakened by pathogenic attack and were rotted. Less than 10% of the pines destroyed were uprooted; they were twisted or broken off at heights ranging from 5 to 20 feet above the ground. The large taproot characteristic of the pines apparently held the trees up; they were not blown down easily, but could be broken. Other trees blown down in adjacent plant communities were *Magnolia grandiflora* (magnolia), *Nyssa biflora* (black gum), *Liquidambar styraciflora* (sweet gum), and *Lireodendrum tulipera* (tulip tree or yellow poplar).

Another survey was conducted on 87 acres of forested land north of Pass Christian in Harrison County, bordering the Wolf River and Red Creek Road. Approximately 10 acres here was bottomland forest along the river and adjacent low-lying drainage areas. The rest of the land was approximately 25 feet above sea level and covered with *Pinus elliotii* (slash), *Pinus taeda* (loblolly) and *Pinus palustris* (longleaf) in various stages of growth. The owner considered the area a game reserve and left it undisturbed. Results of a sample showed that approximately 70% of the bottomland species were blown down. The species were *Magnolia virginiana* (sweet bay) *Liquidambar styraciflora* (sweet gum), *Taxodium distichum* (bald cypress), *Acer rubrum* (red maple), and the area was dominated by *Quercus nigra* (water oak). Ninety per cent of the trees in the low-lying area had diameters greater than 24 inches at breast height and there were between 100 and 150 trees per acre. An estimated total of 201,000 board feet of hardwood timber was lost.

Approximately 10,000 slash, loblolly, and longleaf pine trees with diameters greater than 10 inches were present on the higher sites and there were only 300 of these trees that were not damaged, i.e. 97% were destroyed. Many of those standing were not expected to survive due to lack of limbs, missing tops or split trunks. A total of 607,600 board feet of pine was estimated as lost. Many young trees were crushed by the falling trees, and other understory plants and habitats for wildlife were destroyed. At the time of the survey (March 1970), beetles, especially *Ips avulsus, Ips grandicollis,* and *Ips calligraphus,* had infested many of the downed trees and rot had begun. The specific names of the beetles were furnished by Dr. Virgil Smith, entomologist, U. S. Forest Service, Gulfport, Mississippi. Twisted and split saw logs could not be salvaged for use. Paper wood operations were expected to

be hindered by the tangled mass of trees. Practically all of the pine trees were second growth and ranged from 16 to 68 years old. The water oaks and other hardwoods were much older, ranging from 100 to 125 years.

These two tracts simply show by comparison that the most damage to the vegetation was caused by winds occurring near the center of Hurricane Camille's path.

Another observation was the destruction of *Quercus virginiana* (live oak) along the beach front from Biloxi to Pass Christian. Approximately 25,000 live oaks were growing along the beach before Camille and one-fourth were destroyed by wind and water and one-half were damaged. Those trees nearest the beach were partially inundated and the roots eroded by wave action. The immediate beating action of wind and the physiological "drought" resulting from the salt spray reduced these evergreens to bare branches (Figs. 3 and 4).

Many slash and longleaf pines may have been killed as a result of the inundation of low-lying areas near the mouth of the Wolf and Jourdan Rivers. The trees are dead but standing; however, this could be the result of other, internal damage since many trees on the barrier islands were covered by salt water and survived. This observation needs further study.

The Corps of Engineers, U. S. Army, estimated that a total of 1.2 million board feet of saw timber and one million cords of pulpwood in Mississippi were lost. On the Mississippi Test Facility in Hancock County, an estimated 6,000 cords of pulpwood were damaged and only 60% of the downed trees could be salvaged for lumber. It has been reported that a total of 290 million cubic feet of pine alone was lost in South Mississippi (Van Hooser and Hedlund 1969).

The barrier islands presented a pattern of destruction similar to that on the mainland. Petit Bois Island was affected relatively little but there was a gradual increase in damage on the islands to the west. Horn Island was heavily eroded on the outside beaches. The marsh vegetation was pushed down and pressed to the soil surface by the water as it passed over the island (Figs. 5 and 6). Ship Island was cut into three pieces and more than one-third of the vegetation, most of which was herbaceous, was removed. Cat Island was heavily damaged. Large oaks were uprooted by wave action and many pines were broken by the wind. Large sand dunes were leveled, the sand redistributed over much of the adjacent low-lying marsh. Tons of plant materials swept from the Louisiana marshes and the barrier islands were deposited on the mainland in large windrows.

Marshlands were affected insignificantly because the water covered them early in the hurricane and they were not exposed to the terrific beating of wind and wave that occurred later. *Spartina alter-*

niflora (smooth cord grass) flowered on schedule (September through November). Shrubs found along the periphery of marshes, where they formed thickets, acted as baffles and protected trees and, in some cases, homes. Many upland understory areas were denuded of herbaceous and woody shrubs where they were located near water.

The botanical regime of South Mississippi was disturbed by Hurricane Camille of August 1969, probably to a greater extent than by any other hurricane in the history of Mississippi, and the greatest influence on the terrestrial vegetation was the destruction of the trees.

Figure 1. Heavily damaged pine stand in Hancock County showing parallel but opposite direction alignment of fallen trees. Note direction in which standing trees are leaning.

Figure 2. Heavily damaged pine stand illustrating parallel but opposite direction alignment of fallen trees. This effect was caused by passage of the "eye" of Hurricane Camille through Bay St. Louis-Pass Christian area.

Figure 3. Damaged live oaks (Quercus virginiana) along Highway 90 near Long Beach, Mississippi.

Figure 4. Damaged home and live oak (Quercus virginiana) along Highway 90 and open waters of Mississippi Sound at Long Beach, Mississippi.

Figure 5. Marsh near the south beach of Horn Island. Altitude approximately 1,500 feet.

Figure 6. Low altitude view (600 feet) of same marsh shown in Figure 5. Note flattened plants of *Juncus roemerianus* and *Spartina alterniflora* as a result of wave action across island.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

Protozoan Symbionts from the Anemone *Bunodosoma cavernata* from Galveston Island, Texas

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PROTOZOAN SYMBIONTS FROM THE ANEMONE *Bunodosoma cavernata* FROM GALVESTON ISLAND, TEXAS

by

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Hargitt (1904), in his classic paper on the medusae of the Woods Hole region, noted the susceptibility of medusoid forms to various protozoan parasites. He stated that "when working upon the regeneration of medusae I found several species of Protozoa very closely associated with them and, under the limitations of the aquaria, often exceedingly troublesome, seriously interfering with the progress of the experiments. This suggested the possibility of a parasitic relation." Unfortunately Hargitt made no mention of the taxa of Protozoa involved. Studies regarding protozoan infestations of Cnidaria have been few. Other than the passing references to protozoan infestations by Hargitt (1904) and Kudo (1966) there have been no intensive studies of protozoan parasites or symbionts of marine Cnidaria.

The anemone *Bunodosoma cavernata* is a common inhabitant of the Texas coast and cursory observation revealed a large complement of protozoan associates. These included *Saprodinium, Euplotes, Paraeuplotes, Vorticella, Cohnilembus, Anophrys, Uronema* and *Vahlkampfia.*

Approximately forty anemones were collected from jetty rocks on Galveston Island on 3 November 1970. Note was made within one day of protozoans found on the external surfaces, in the coelenteron and in surrounding sea water. The anemones were kept until 7 December 1970 under varying conditions and bi-weekly note was made of the associated protozoan fauna.

One group of six anemones was placed in a 29-gallon aquarium in which the salinity was maintained at 28 g/kg and the temperature ranged from 15 to 18°C. These anemones were considered "normal." No attempt was made to construct a facsimile of the Galveston littoral environment from which the anemones were removed. Other groups of three to eight anemones were kept in 1.5-gallon aquaria (salinity 28 g/kg, temp. 18°C) and in 12-inch finger bowls wherein salinity and temperature were varied. For one group (GP 1) the salinity was allowed to rise by evaporation from 20 g/kg to 40 g/kg over a 12-day period. In a second group (GP 2) the sea water was flushed out and

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replaced with clean sea water of the same salinity every 3 days for a 3-week interval. In the third group (GP 3), the salinity was constantly maintained at 24 g/kg for 4 weeks. All three groups were maintained at 18°C. In a fourth group temperature was maintained at 24°C. Salinity was routinely monitored on a daily basis with a Goldberg refractometer. Microscopy examinations were made every 2 to 4 days using wet mounts of anemone mucus, coelenteron contents, tissue squashes and the external medium.

Protozoans found as epizoites or symbionts on the anemones as well as site of infection and relative abundance are listed in Table 1.

Table 1.

Protozoa Found in Association with Anemones after Two Weeks in the Laboratory

Protozoan	Site of Infection			Size Range (microns)
	Wounds	Coelenteron	Mucus Coat	
Vahlkampfia	XXX	XX	XX	7-30
Saprodinium	XX	X	X	21-25
Euplotes	XXX	XXX	XXX	70-140
Paraeuplotes	X	X	X	50-80
Paramecium			X	100-150
Vorticella	XX	XX	XX	c.150
Cohnilembus	X	X	XX	30-80
Anophrys	XX	XX	XX	60-90
Uronema	X	X	X	20-40

X indicates rarity; XX indicates frequent occurrence; XXX indicates dominant organisms numerically.

These data were taken 2 weeks after the anemones were removed from the natural environment and introduced into the laboratory. Initially when first placed in aquaria all Protozoa found in association with the anemones occurred in very low numbers when compared to the situation after 2 weeks. Protozoa in habitat sea water included very sparse populations of *Euplotes*, *Paramecium* and *Vorticella*. The normal anemones maintained a numerically smaller symbiont population than those in the finger bowls. Those in the 1.5-gallon aquaria had a "normal" symbiont complement also. In GP 2, where the water was flushed out and replaced periodically, the anemones retained the normal fauna

and did not support large populations of any species of protozoan. In the group maintained at 24°C the anemones became moribund after two weeks and developed extremely large populations of ciliates, especially *Euplotes*, *Anophrys* and *Saprodinium*, as well as large numbers of the naegleriid amoeba *Vahlkampfia*. In addition to being found in necrotic and normal anemone tissues this amoeba was also found in large numbers in the fouled medium. Both cysts and trophozoites of *Vahlkampfia* were extremely numerous at sites of necrosis. In group 3 (GP 3), wherein conditions were constant, the anemones survived up to 4 weeks at which time they became moribund and died. The same situation prevailed here as with respect to GP 2. In GP 1 increased salinity had no apparent effect on protozoan numbers although individual *Euplotes* showed considerable size increase (up to 250 μ in length). Size ranges of all associative Protozoa encountered are given in Table 1.

All anemones within the finger bowls died within 5 weeks. In all cases the anemones were infiltrated by large numbers of bacteria and large populations of *Euplotes* and *Vahlkampfia*. Approximately half the *Euplotes* in association with necrotic anemone tissue were in the process of conjugation.

Three morphological types of *Vahlkampfia* were observed. Most amoebae were 7–10 μ in length and formed only one broad, fan-shaped pseudopod which, moreover, consisted mainly of a large hyaline area. Formation of a new pseudopod was preceded by flooding the old pseudopod with granular endoplasm and the formation of a new hyaline bulge. Rate of pseudopod formation was hastened by the heat of a substage illuminator. The second observed trophozoite stage was considerably larger (25–30 μ) and had numerous psuedopodia. Their morphology approached that of the former type after being on a microscope slide (above an illuminator) for several minutes. These larger amoebae underwent division and "reverted" to the smaller, monopseudopodial type. On two occasions a nucleus (2–3 μ in diameter) with a large endosome was observed in the large amoebic variant. Large numbers of *Vahlkampfia* cysts were found in decaying and moribund anemones as well as in putrefying media. After being on a microscope slide for about 5 minutes, above a substage illuminator, these cysts released one amoeba each. Cysts were rounded, considerably flattened, had wrinkled surfaces and were between 5–9 μ in diameter. *Vahlkampfia* invades anemone tissue and will emerge from tissue fragments when heated by substage illumination for a few minutes. The amoebae can be demonstrated in both normal and necrotic tissue, the greatest concentration of amoebae occurring in necrotic tissues with a large bacterial population. The amoebae were observed to ingest bacteria, indicating that greater degree of association with necrotic tissue may be due to greater availability of food organisms in necrotic as opposed to healthy tissue. Other Protozoa, especially *Eu-*

plotes, showed greater abundance where there was high bacterial density.

Vahlkampfia and at least a few of the ciliates (*Euplotes, Paraeuplotes, Saprodinium* and *Vorticella*) are not obligate symbionts. Naegleriid amoebae are known as facultative parasites from a wide variety of organisms including rodents (Wilson et al. 1967), molluscs (Hogue 1921 and Richards 1970), insects (Page 1970) and man (Cerva and Novak 1968 and Duma et al. 1969). Apparently amoebae of this group can be demonstrated to be symbiotic with most any metazoan. Although *Naegleria gruberi* is the only naegleriid amoeba definitely known to be a causative agent in human amoebic meningoencephalitis (Duma et al. 1969 and Cerva 1970), the remaining naegleriids cannot be discounted as potential pathogens. Wilson et al. (1967) demonstrated that *Vahlkampfia* as well as many other genera of amoebae can cause systemic amoebiasis in rodents following hypodermic inoculation. Available data indicate that *Vahlkampfia*, and at least some of the ciliates in this study feed on broken tissue and associated bacterial flora. The external mucus coat or pellicle of the anemone on normal anemones has a relatively large bacterial population and this may account for the establishment of larger populations of Protozoa in this region when compared to other anatomical regions of the anemone.

The hymenostomid genera *Cohnilembus* and *Anophrys* are interesting in that they are known to be intestinal symbionts of echinoids (Kudo 1966). These two genera and *Uronema* predominantly occur in the coelenteron and mucus coat. *Paraeuplotes*, found here on anemones, is also a known epizoite of corals (Kudo 1966).

In the normal littoral habitat the anemones are periodically exposed to the air during tidal cycles and there is considerable scouring of the anemone surface as well as drastic short term salinity and temperature changes in the immediate environment of the anemone. These environmental factors probably serve to control bacterial and protozoan populations epizootic on the anemones. Conversely the mucus sheath of the anemone, which serves for attachment of protective shell fragments and other debris to the anemone surfaces, may prevent desiccation at low tide and may act as a suitable substrate for the establishment of epizoites. When exposed the anemones close the oral apparatus, trapping sea water and any associated microfauna possibly allowing survival of some associative forms. It remains to be determined whether or not any of these symbionts or epizoites are dependent on the anemone for life cycle completion.

Euplotes is by far the most abundant of all the ciliates encountered and conjugation is a commonplace phenomenon especially when putrefaction is well advanced. It is possible that death of the anemone enables or induces conjugation in *Euplotes*.

Anemones of the littoral zone support an extensive protozoan fauna. Although none of the Protozoa involved are definitely known to be obligate symbionts there is a distinct association. Most of the forms are facultative symbionts, especially *Vahlkampfia* and *Euplotes*. *Vahlkampfia* invasion of anemone tissues can to some extent be associated with necrotic tissue changes and increased bacterial populations. Most probably bacteria initiate the necrosis and the large bacterial populations allow for increase in the amoeba population. No causal relationship has been established.

ACKNOWLEDGEMENTS

I would like to thank Doctors K. Horvath and S. H. Hopkins (Department of Biology, Texas A&M University) for critical review of the manuscript.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

Some Analyses of Twentieth Century Landing Statistics of Marine Shrimp of the South Atlantic and Gulf States of the United States

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DOI: 10.18785/grr.0402.06

SOME ANALYSES OF TWENTIETH CENTURY LANDING STATISTICS OF MARINE SHRIMP OF THE SOUTH ATLANTIC AND GULF STATES OF THE UNITED STATES

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ABSTRACT

There is a strong correlation between the total catch of white and brown shrimp with dockside prices on the United States Gulf Coast since 1902, but there is no significant correlation between South Atlantic production and prices, probably because the South Atlantic shrimp stocks have been over-fished since the 1920s. There is no negative or positive correlation between the catch statistics of brown and white shrimp of the United States, and these species seem to be weakly competitive, if at all. There is a significant correlation between the annual production of South Atlantic and Gulf white shrimp, but there is none between South Atlantic and Gulf brown shrimp, possibly because the brown shrimp live generally in deeper water and are not so much influenced by short term variations in climatic conditions as the white shrimp are in shallow water. In furtherance of this idea, there is some indication that the brown shrimp production is less variable than the white shrimp production.

INTRODUCTION

Three species of shrimp of the Family Penaeidae (Genus *Penaeus*) are present in considerable numbers and in overlapping distributions in the bays and oceanic shallow waters from Cape Hatteras, North Carolina, south to Texas and beyond. These are the white shrimp *Penaeus fluviatilis*, the brown shrimp *P. aztecus*, and the pink shrimp *P. duorarum*.

Another shallow water penaeid *Penaeus brasiliensis* exists only in such small numbers off Miami, Florida that it was overlooked by biologists of the area until discovered there by Eldred (1960). A fifth species of the Penaeidae, *Xiphopeneus kroyeri*, is almost entirely shallow oceanic in distribution with a few entering the bays in cool weather (Gunter 1950). It is not found along the South Atlantic part of the United States in commercial concentrations, but has been fished in the Gulf since boats and seines large enough to fish the shallow offshore waters have been available.

The white shrimp grows to large size in shallow waters of the bays. The other two species of commercial shrimp, *P. aztecus* and *P. duorarum*, do not grow so large in the bays and shallows and do not school as strongly as the white shrimp and the seabob. They also go into deeper waters when they move into the open ocean.

SOME HISTORICAL ANTECEDENTS

Indians caught shrimp with the use of dipnets, seines and leafy weirs such as are still employed in the Rio Soto la Marina, Mexico. Shrimp from the North Carolina waters were caught and transported to the Philadelphia market when Thomas Say (1817) first described the North American white shrimp.

Catch statistics on the commercial fisheries were collected only after the organization of the United States Fish Commission by S. F. Baird and others in 1871. We may assume with complete assurance, however, that shrimp production grew with the increase in population up until recent years. Even in the early part of this century the catching of shrimp was by means of dipnets, seines, and castnets. For this reason only the white shrimp *P. fluviatilis* and the seabob *Xiphopeneus kroyeri* were taken, because they were schooling shrimp. Even so the seabob has been taken in small numbers amounting to about 1.2% of the Gulf catch, (cf. Gunter 1962) partly because of its small size and its open ocean distribution. This shrimp is much more important, relatively, in South American waters (cf. Lindner 1957).

The otter trawl came into use along with motor vessels on the South Atlantic Coast during the period of World War I and spread quickly to the Gulf Coast. This permitted the fishing of deep waters and larger shrimp, which move out as they grow older. Thus, production gradually rose with the increase of demand and the more efficient otter trawl put the large seine crews out of business in Louisiana in the early 1930s.

From 1902 the shrimp production in this country increased into the early 1950s. In the 1940s an extreme drought caused a great shortage of white shrimp, especially in Texas waters, and there fishermen turned to the previously unfished brown shrimp which were caught predominantly at night. Most states had laws against shrimping at night for the protection of the white shrimp, the idea being that they should not be harassed all hours of the twenty-four. The large brown shrimp generally bury in the bottom during the day. Recognition of these facts led to exploitation of the brown shrimp and after the early '50s it has yielded more than the white shrimp. This development began in Texas waters in 1947 and spread quickly to other areas on the Gulf and South Atlantic Coast. Even so, the separation of the brown and white shrimp was not begun in the federal fisheries statistics until

1957. Therefore, we may say that the shrimp production figures used here were comprised almost entirely of white shrimp from 1903 to 1948, with about 1% being seabobs. From 1948 to 1957 there was a period of production when the brown shrimp and white shrimp were not separated. After 1957 these shrimp have been separated in the catch statistics of the South Atlantic and Gulf Coasts. At that time the seabobs were also separated in the statistics.

From 1951 to 1956 inclusive, the heads-off weight of white and brown shrimp produced ranged between 126 and 146 million pounds and in the 1967–71 period it ranged from 125 to 137 million pounds. These are the only years, except for 1963, that the United States shrimp production has ever ranged above 100,000,000 pounds of headless shrimp. The 1951–56 high production was due to the exploitation of the previously unfished population of brown shrimp plus the white shrimp. The more recent high production seems to be due to an increase in the white shrimp population, caused possibly by a recent hyperfertilization of the bays.

DISTRIBUTIONS AND CATCH RECORDS

There are many interesting things about the distribution of the shallow water penaeids along the coasts of the South Atlantic and Gulf states and Mexico, but here we are concerned only with the brown shrimp *P. aztecus* and the white shrimp *P. fluviatilis*, because these two have been the chief commercial producers and they both grow up in estuarine areas. Furthermore the United States population of brown and white shrimp are quite discrete and disconnected from other populations, and we have United States production of these two species unmixed with foreign populations.

The white shrimp population of the United States is divided into two distinct parts. The South Atlantic component runs along the coast from North Carolina with the greatest abundance in Georgia and gives out at about the St. Lucie inlet in south Florida (Gunter and Hall 1963). The second population extends from the west Florida panhandle to Aransas Bay, Texas.

The brown shrimp has roughly the same distribution but it is less numerous on the Atlantic and extends farther south seasonally in the Mexican waters. Its abundance is greater in the salt waters of Texas than that of the white shrimp, which is most abundant in Louisiana because of the lower salinities in that region. In Texas waters brown shrimp are not raised in appreciable numbers farther south than the Aransas–Corpus Christi Bay system, which is connected to the Gulf by Aransas Pass. During the fall both species leave the bays and go to outside waters. Gunter (1962) showed by following the seasonal catch statistics of four areas on the coast that the white and

brown shrimp go south on the Texas coast in the early fall and winter. Some go into Mexico and return in diminished numbers in the spring to Texas waters. Catches made off northern Mexico are returned to United States ports. This movement apparently begins off Galveston Bay and covers a distance of some 400 miles and it is virtually a parallel case to the seasonal north to south white shrimp migration and return from Georgia to the region of Cape Canaveral discovered by Weymouth, Lindner and Anderson (1933) (Lindner and Anderson 1956).

Pink shrimp exist in fair concentrations off North Carolina and in heavy concentrations off the Tortugas. There are also large concentrations in the Bay of Campeche, Mexico, which were formerly fished by Florida, Texas, Cuban, and Mexican fishermen, and adequate statistics are not available. Former United States catch statistics of this species were confused by Florida and Texas boats bringing in Campeche shrimp. Furthermore Gulf and Atlantic catches were confused by shrimpers carrying some shrimp from Tortugas to Atlantic ports. For these reasons we have avoided use of pink shrimp statistics. As grooved shrimp they were mixed with the browns to a small extent in the late 1950s but not enough to vitiate the brown shrimp statistics.

SUMMARY OF THE PROBLEM

The brown and white shrimp both grow up in the bays of the northern Gulf Coast and the South Atlantic states. They have a differential distribution with relation to salinity and season (Weymouth, Lindner and Anderson 1933, Gunter 1950, 1961, Gunter, Christmas and Killebrew 1964). The white shrimp come in and move out later in the year. Furthermore the white shrimp grow to larger size in the estuaries and, therefore, are more heavily fished before they move outside. As a matter of fact the whole shrimp industry grew up in the shallows and gained technical experience on the white shrimp before moving to the open sea.

Because of the overlapping life history of these two species of commercial shrimp, both in time and place, the question has arisen concerning their competition. Therefore, some who have been concerned with shrimp biology have discussed these matters for years, mostly with the suspicion that there was some kind of competition that opposed one shrimp population to the other. These ideas were the genesis of the analyses offered here.

All shrimp statistics used here were taken from the annual Fishery Statistics of the United States and its predecessors, of which the latest issue is Lyles (1969), and preliminary pamphlets.

PRICES AND PRODUCTION

One would think that prices increased with expansion of production, the demand for shrimp, etc., and such is the case where total United States production and price are concerned. The coefficient of correlation, r, for the figures shown in Table 1 is 0.691 with 39 observations and 37 degrees of freedom. This means that prices and production have grown together, and the correlation is significant within the 1% level.

Table 1.

The Total Catch of White and Brown Shrimp of the Gulf and South Atlantic Coasts of the United States in Thousands of Pounds and the Dockside Value in Thousands of Dollars

Year	Catch in Pounds	Value	Year	Catch in Pounds	Value
1902	10,506	286	1953	145,414	76,267
1908	11,855	408	1954	172,596	60,535
1918	40,632	1,746	1955	156,454	61,404
1923	45,987	2,593	1956	142,297	70,305
1927	64,200	3,518	1957	90,364	72,438
1928	74,986	4,550	1958	89,903	71,829
1929	70,487	4,435	1959	108,548	56,875
1930	57,219	2,996	1960	112,088	66,143
1931	62,628	2,731	1961	64,234	50,589
1932	57,313	2,036	1962	77,788	71,832
1934	77,479	3,067	1963	112,535	68,785
1936	76,520	3,778	1964	95,813	69,328
1937	90,866	5,009	1965	111,643	81,067
1938	96,150	4,848	1966	107,041	93,784
1939	96,150	4,848	1967	137,837	99,584
1940	97,754	5,895	1968	124,480	109,833
1945	122,743	21,289	1969	126,331	117,317
1950	122,048	43,144	1970	139,437	119,569
1951	143,780	51,518	1971	148,125	143,362
1952	145,414	54,755			

A further breakdown shows that the correlation, r, between price and production on the Gulf Coast amounts to 0.737 which is even more significant (Table 2). The Gulf correlation is higher than that of price

Table 2.

The Catch of United States Gulf Coast Brown and White Shrimp in Thousands of Pounds and Thousands of Dollars

Year	Pounds	Value	Year	Pounds	Value
1902	8,031	199	1953	145,781	66,336
1908	8,156	270	1954	153,995	53,652
1918	30,466	1,276	1955	137,923	54,465
1923	30,595	1,771	1956	125,727	62,499
1927	44,725	2,344	1957	74,760	63,288
1928	53,357	3,092	1958	76,992	63,871
1929	50,468	2,986	1959	94,362	50,348
1930	40,203	2,017	1960	94,276	57,631
1931	46,075	1,817	1961	53,574	43,650
1932	42,427	1,400	1962	64,582	60,557
1934	60,621	2,278	1963	103,067	63,539
1936	54,723	2,756	1964	86,139	62,695
1937	73,050	4,181	1965	96,010	70,907
1938	73,108	3,725	1966	93,886	82,971
1939	78,173	3,991	1967	125,862	90,574
1940	83,012	5,141	1968	109,799	95,837
1945	94,444	17,305	1969	110,723	101,131
1950	98,359	33,112	1970	126,897	108,183
1951	125,747	44,136	1971	129,850	123,770
1952	128,745	48,170			

and production of total shrimp, of the South Atlantic and Gulf combined.

In contrast, the correlation between price and total catch on the South Atlantic Coast, Table 3, is 0.067, which is not significant at all. This somewhat anomalous conclusion becomes clear if the shrimp of the South Atlantic Coast were over-fished rather early in the development of this fishery and have been over-fished for years. This explanation was advanced by Mr. Milton J. Lindner, whose experience with the South Atlantic shrimp fishery began in 1930. Examination of Table 3 shows that high production in white shrimp on the Atlantic Coast was attained in the 1920s. Apparently these shrimp were fished to the very limit of their yield and have been for a great number of years. This seems to be the only reasonable explanation of the fact that price level and shrimp production have not increased together on

Table 3.

The Catch and Values of White and Brown Shrimp in Thousands of Pounds and Thousands of Dollars for the South Atlantic

Year	Pounds	Value	Year	Pounds	Value
1902	2,475	87	1953	21,385	9,931
1908	3,699	138	1954	18,601	6,883
1918	10,166	470	1955	18,531	6,939
1923	15,392	822	1956	16,570	7,806
1927	19,475	1,174	1957	15,604	9,150
1928	21,629	1,458	1958	12,911	7,958
1929	20,019	1,449	1959	14,186	6,527
1930	17,016	979	1960	17,812	8,512
1931	16,553	914	1961	10,660	6,939
1932	14,586	636	1962	13,206	11,275
1934	16,858	789	1963	9,468	5,246
1936	21,797	1,022	1964	9,674	6,633
1937	17,816	828	1965	15,633	10,160
1938	17,899	821	1966	13,155	10,813
1939	17,977	857	1967	11,975	9,010
1940	14,742	754	1968	14,681	13,996
1945	28,299	3,984	1969	15,608	16,186
1950	23,689	10,032	1970	12,541	11,386
1951	18,033	7,382	1971	18,275	19,592
1952	16,669	6,585			

the South Atlantic Coast, but have increased together on the Gulf Coast.

It may be further assumed that if the Gulf fishing continues at a high level with a continued price rise, that the production of Gulf shrimp will reach a limit, if it has not already done so, and that in future times price and shrimp production on the Gulf Coast will no longer show a correlation.

PRODUCTION FIGURES BY AREAS AND SPECIES

Because of previous correlations noted between the production of white shrimp and rainfall in the State of Texas (Gunter and Edwards 1969) and the apparent preference of brown shrimp for higher salinities, we determined the correlations between the catch of whites

and browns in the State, r equaled —0.2151, but with only 14 degrees of freedom it was not significant.

Similarly there was no significant correlation between the catch of browns and whites on the South Atlantic Coast, the Gulf Coast, or the total of both areas. This means apparently that the production of these two shrimp are not closely related to one another and that they have different ecological niches and are weakly competitive, if at all.

On the other hand, there is a correlation between the total annual production of shrimp of the South Atlantic with the total annual production in the Gulf, in which r equals 0.3261 with 37 degrees of freedom (Table 4). This is significant at the level of 5.0%. This would mean that when conditions are generally good for shrimp production on the Gulf, they are also good on the Atlantic. Most likely these con-

Table 4.

Comparison of South Atlantic and Gulf Catches of White and Brown Shrimp in Thousands of Pounds

Year	Atlantic	Gulf	Year	Atlantic	Gulf
1902	2,475	8,031	1953	21,355	145,781
1908	3,699	8,156	1954	18,601	153,995
1918	10,166	30,466	1955	18,531	137,923
1923	15,392	30,595	1956	16,570	125,727
1927	19,475	44,725	1957	15,604	74,760
1928	21,629	53,357	1958	12,911	76,992
1929	20,019	50,468	1959	14,186	94,362
1930	17,016	40,203	1960	17,812	94,276
1931	16,553	46,075	1961	10,660	53,574
1932	14,586	42,727	1962	13,206	64,582
1934	16,858	60,621	1963	9,468	103,067
1936	21,797	54,723	1964	9,674	86,139
1937	17,816	73,050	1965	15,633	96,010
1938	17,899	73,108	1966	13,155	93,886
1939	17,977	78,173	1967	11,975	125,862
1940	14,742	83,012	1968	14,681	109,799
1945	28,299	94,444	1969	15,608	110,723
1950	23,689	98,359	1970	12,541	126,897
1951	18,033	125,747	1971	18,275	129,850
1952	16,669	128,745			

ditions are of a broad climatic nature, involving such things as cool and warm years, high rainfall and droughts, and even hard cold waves. It would be quite difficult to get some of these factors into figures or numbers, especially comparable figures for statistical calculations, even if the climatic events were recorded years ago as many were not. Therefore, we will pass this question by.

Similarly there is a very strong correlation between the white shrimp production of the Atlantic Coast and Gulf Coast (Table 5).

Table 5.

Catch Figures for South Atlantic and Gulf White Shrimp in Thousands of Pounds

Year	Atlantic	Gulf	Year	Atlantic	Gulf
1902	2,475	8,031	1945	28,299	94,444
1908	3,699	8,156	1957	9,554	11,129
1918	10,166	30,466	1958	7,204	25,740
1923	15,392	30,595	1959	8,326	24,574
1927	19,475	44,725	1960	12,200	28,381
1928	21,629	53,357	1961	9,113	14,421
1929	20,019	50,468	1962	7,879	23,166
1930	17,016	40,203	1963	4,719	47,087
1931	16,553	46,075	1964	5,272	43,978
1932	14,586	42,727	1965	10,587	33,599
1934	16,858	60,621	1966	5,948	29,917
1936	21,797	54,723	1967	7,020	24,960
1937	17,816	73,050	1968	11,004	30,918
1938	17,899	73,108	1969	10,294	44,959
1939	17,977	78,173	1970	8,111	45,962
1940	14,742	83,012	1971	12,077	42,010

The total series stemming from 1902 to 1971 has 29 degrees of the freedom, because the years 1948 to 1957 were excluded when brown shrimp and white shrimp were not properly separated in the fisheries statistics. The correlation r was found to be 0.655 and significant at the 1% level.

In contrast, no such correlation can be shown between the brown shrimp catch of the South Atlantic and Gulf (Table 6). We may spec-

Table 6.

Atlantic and Gulf Brown Shrimp Production in Thousands of Pounds and the Totals

Year	Atlantic	Gulf	Atlantic and Gulf browns combined
1957	6,050	63,631	69,681
1958	5,707	51,252	56,959
1959	5,860	69,788	75,648
1960	5,612	65,895	71,507
1961	1,547	39,153	40,700
1962	7,164	41,416	48,580
1963	4,749	55,980	60,729
1964	4,402	42,161	46,563
1965	5,046	62,411	67,457
1966	7,207	63,969	71,176
1967	4,955	100,902	105,857
1968	3,677	78,881	82,558
1969	5,314	65,764	71,078
1970	4,430	80,934	85,364
1971	6,060	87,788	93,848

ulate here that brown shrimp spend a shorter time in the bays, and live in deeper water in the ocean, and for that reason would be less affected by climatic variations than the white shrimp in shallower water. Thus production would be less subject to parallel variations induced by climatic variables in shallow water, all leading to greater correlations of the white shrimp catch on the two coasts.

We pursued this idea a little further and compared the coefficient of variation of the brown and white shrimp catches (Table 7). The coefficient of variation for the brown shrimp was 25.918 and for the white shrimp was 28.569. A comparison of the significance of differences between two variants showed that this was significant at the classical 95% level. This means that the brown shrimp production is probably less variable than the white shrimp production on the United States coast, and possibly a longer series of data will clarify this point.

A list of significant correlations determined in this study and a list of correlations which are not statistically significant are given in Tables 8 and 9, respectively.

Table 7.

Total Brown and White Shrimp Catches of the United States in Thousands of Pounds

Year	Browns	Whites
1957	69,681	20,683
1958	56,959	32,944
1959	75,648	32,900
1960	71,507	40,581
1961	40,700	23,534
1962	48,580	29,208
1963	60,729	51,806
1964	46,563	49,250
1965	67,457	44,186
1966	71,176	35,865
1967	105,857	31,980
1968	82,558	41,922
1969	71,078	55,253
1970	85,364	54,073
1971	93,849	54,087

Table 8.

A List of Significant Correlations Determined in this Study

	Degrees of Freedom	r	Significance
1. South Atlantic and Gulf browns and whites vs. values......	37	0.6912	1.0%
2. Gulf browns and whites vs. values......	37	0.7368	0.1%
3. South Atlantic browns and whites vs. Gulf browns and whites............	37	0.3261	5.0%
4. Atlantic whites vs. Gulf whites........	32	0.6550	1.0%

Table 9.

A List of Correlations Determined in this Study that are not Statistically Significant

	Degrees of Freedom	r
1. South Atlantic grooved vs. whites.................	15	-0.003
2. Gulf grooved vs. white shrimp....................	16	0.094
3. South Atlantic browns vs. whites.................	15	-0.065
4. Gulf browns vs. whites.....	16	0.051
5. South Atlantic and Gulf browns vs. South Atlantic and Gulf whites.....................	13	0.2790
6. Texas grooved vs. whites.....................	16	-0.148
7. Texas browns vs. whites.....................	16	-0.215
8. South Atlantic browns and whites vs. value.......	39	0.0674
9. South Atlantic browns vs. Gulf browns............	15	0.121

SUMMARY

There are five species of commercial penaeid shrimp extending from Cape Hatteras, North Carolina to northern Mexico. One is localized in Biscayne Bay, Florida and one is only produced in low percentage (less than 2%) of the total catch in the Gulf of Mexico. A third species, the pink shrimp, has had foreign catches so mixed with the domestic production that local figures on the Gulf Coast for past years are not reliable. Fairly adequate production figures for white shrimp are available for the years 1902 to 1947 and 1958 to the present. From 1948 to 1957 the brown and white shrimp catches were mixed and to some extent with the pinks. After 1958 all species were separated in the catch records.

There is a strong positive correlation between total shrimp production of the United States and value (dockside price) of the shrimp, and an even more significant correlation between Gulf production and value. In contrast the much smaller South Atlantic shrimp catch shows no correlation with prices, probably because the stock has been fished to capacity since the 1920s, when production limits seem to have been obtained.

A strong correlation exists between white shrimp production of the South Atlantic and the Gulf, while none was found for the brown shrimp production of the two areas. A possible explanation for this fact is the deeper water distribution of the brown shrimp, which means a more stable environment, less affected by general climatic oscillations which influence white shrimp in shallow waters and cause similar variations in the two populations.

There is no significant correlation between the total United States production of white and brown shrimp, either positively or negatively, nor are there any correlations of the South Atlantic and Gulf areas considered separately. This means that the brown and white shrimp are weakly competitive, if at all.

We wish to thank Mr. Paul Poole, data processor at the Gulf Coast Research Laboratory, for his assistance in the statistical analyses.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

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DOI: 10.18785/grr.0402.07

EFFECT OF HOLOTHURIN ON SARCOMA 180 AND B-16 MELANOMA TUMORS IN MICE[1]

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ABSTRACT

Holothurin, a biotoxic principle from the Cuvierian glands of the Bahamian sea-cucumber, *Actinopyga agassizi,* was studied as an anti-tumor agent capable of retarding tumor growth and prolonging the life of tumor-bearing mice. White Swiss mice injected with Sarcoma 180 had a mean survival time of 18.1 days with an average weight gain representing tumor and ascites fluid accumulation amounting to 25.1 grams in 15 days. Of five white Swiss mice with Sarcoma 180 receiving 0.15 mg Holothurin every other day, one was alive at 57 days and the average weight gain of the group was 10.4 grams in 15 days. White Swiss mice with Sarcoma 180 which survived the lethal effects of slightly higher doses of Holothurin also had prolonged survival times and negligible tumor growth. C57-B1-6J mice with B-16 melanoma tumors did not show increased survival time using the same doses of Holothurin that were effective in white Swiss mice. Toxicity tests indicated that the safe upper limit for intraperitoneal Holothurin injection in white Swiss mice was 0.10 mg/day, 0.15 mg given every other day, and up to 0.30 mg given in a single injection. Similar tests with C57 black mice showed survival with as much as 0.60 mg Holothurin in a single subcutaneous injection. Holothurin was found to be 250 to 500 times more effective in causing red blood cell hemolysis than saponin and thus appears to have some action on living cells in addition to its surfactant action.

INTRODUCTION

Cancer chemotherapy began in 1946 when nitrogen mustard was used in treating leukemia patients. During the next 15 years only some thirty drugs were used in cancer chemotherapy but screening of many thousands of compounds was carried out each year (Clark 1961). Although marine invertebrates provide a particularly rich source of compounds with biological activity in mammalian species, less than

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1% of all marine invertebrates thought to possess biotoxic substances have been investigated and of those, only a dozen have been thoroughly investigated pharmacologically (Halstead 1965).

Small concentrations of a crude water extract made from the whole body of the Bahamian sea-cucumber, *Actinopyga agassizi,* was found to be lethal to mice and fish and to have some tumor cell inhibitory action *in vitro* (Nigrelli and Zahl 1952). The active principle of this crude extract was found to be concentrated in the Cuvierian tubules located in the sea-cucumber respiratory tree and was named Holothurin (Chanley et al. 1955). Holothurin was the first known steroid saponin of animal origin (Nigrelli et al. 1959). Chemical analysis of Holothurin indicates that it is highly soluble in water, non-volatile, heat stable, and exhibits surface-active properties (Nigrelli and Jakowska 1960). Holothurin appears to consist of a few steroid aglycones that are bound individually to four monosaccharide molecules. A provisional formula has been proposed (Alender and Russell 1966). See Fig. 1.

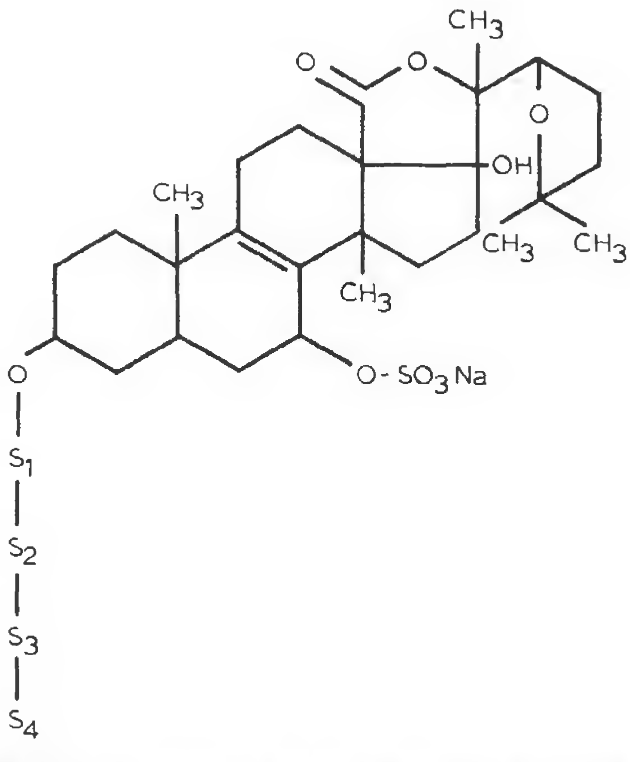

Figure 1. Holothurin formula. Proposed structure for Holothurin molecule, a steroid saponin of animal origin; the monosaccharide groups represented by S_1-S_4 are, respectively, D-glucose, D-xylose, D-quinovose, and 3-o-methyl glucose.

Holothurin is highly toxic to many types of organisms in very small concentrations. It retards onion root tip development (Nigrelli and Jakowska 1960) and fruit fly pupation (Goldsmith, Osburg and Nigrelli 1958) at 1000 ppm, alters regeneration of planarians at 100 ppm (Quaglio et al. 1957), is lethal to the "pearl" fish *Carapus* at 1 ppm and affects sea urchin development at 0.01 ppm (Ruggieri and Nigrelli 1960). Holothurin exhibits a hemolytic effect on red blood cells and reduces the size of a subcutaneously injected Sarcoma 180 tumor in white Swiss mice (Nigrelli 1952). Krebs-2 ascites tumors in white Swiss mice are also inhibited by Holothurin (Sullivan, Ladue and Nigrelli 1955).

The present study demonstrates inhibition of Sarcoma 180 tumors in white Swiss mice but not of B-16 melanoma tumors in C57 Black 6J mice. Toxicity of Holothurin was estimated by measuring its effects on red blood cell hemolysis and by lethal-dose measurements in mice. It appears that the anti-tumor activity of Holothurin is not only dose-dependent but that the effective dose is determined by the sensitivity of the species to the lethal effects of Holothurin.

MATERIALS AND METHODS

Holothurin: The Holothurin referred to in this paper was a "crude extract" obtained from Dr. Ross Nigrelli and was made from the sun-dried, powdered Cuvierian glands of Bahamian sea-cucumbers, *Actinopyga agassizi*.

Red Blood Cell Hemolysis Tests Using Holothurin and Saponin: Fresh red blood cells were obtained from white Swiss mice just prior to testing the hemolytic effects of Holothurin and saponin of plant origin. The blood was obtained by cardiac puncture while the mice were under light ether anesthesia. Approximately 5 ml of blood was diluted in 100 ml of balanced-saline solution buffered at pH 7.4 (Olmsted 1967) containing calcium oxalate (0.1%) to prevent coagulation. A serial dilution of Holothurin was prepared ranging from 2 mg/ml to 0.001 mg/ml and a similar series of dilutions of saponin was made for comparison.

One ml of diluted blood was added to 5 ml of each of several concentrations of both Holothurin and saponin. The test tube was centrifuged 1 minute after mixing the contents and the optical density of the supernatant was measured using a spectrophotometer set at 540 mu. The degree of hemolysis was estimated by the concentration of hemoglobin in the supernatant. These values were compared to 100% hemolysis values obtained either by using water only as the diluent or by using a high concentration of Holothurin or saponin.

Holothurin Toxicity in Mice: All Holothurin injections were given at dosages determined by previous tests done in this laboratory

on normal, non-tumor-bearing mice. Tests to determine the lethal and sub-lethal intraperitoneal doses of Holothurin in white Swiss mice were carried out using several concentrations given daily, given on alternate days, and for several concentrations given in a single injection. The dosages of Holothurin given to the white Swiss mice bearing Sarcoma 180 tumors were based on these data. The dosages of Holothurin given to the C57 black mice bearing B-16 melanoma tumors was based on the effective doses of Holothurin given to tumor-bearing white Swiss mice. In addition, a test of toxicity of a single subcutaneous injection of Holothurin was carried out using several concentrations of Holothurin given to normal, non-tumor-bearing C57-B1-6J mice.

Holothurin Administration to Mice Bearing Sarcoma 180: Sarcoma 180 cells and the white Swiss mice were obtained from the Gulf South Research Institute in New Orleans. The mice were inoculated intraperitoneally with 0.5 ml of Sarcoma 180 ascites fluid containing 11.6×10^6 cells/ml. Groups of five mice received daily injections of Holothurin at 0.01, 0.05, 0.10, and 0.15 mg each, and three groups received injections of Holothurin every other day in the amounts of 0.10, 0.15 and 0.20 mg each. Twelve mice received Sarcoma 180 inoculations, but no Holothurin. The survival time was recorded for each mouse and the mice were weighed individually before inoculation with tumor cells and at 5-day intervals during the course of the experiments.

Holothurin Administration to Mice Bearing B-16 Melanoma: A single C57-B1-6J mouse with a B-16 melanoma tumor was used as the source for all of the B-16 melanoma used in this study. The tumor-bearing donor mouse was obtained from the Department of Surgery at Tulane Medical School. The C57-B1-6J mice used in the experiments here were obtained from the Roscoe B. Jackson Memorial Laboratory in Bar Harbor, Maine. The solid tumor was taken from the donor mouse under light ether anesthesia and was minced with scissors in a tissue culture nutrient medium containing serum (Olmsted 1967). Several small pieces of the minced tumor were trochared subcutaneously into the left side of thirty-five recipient male mice. Thirty of these mice were used for the experiments reported here. Daily injections of 0.05, 0.10, and 0.15 mg Holothurin were given to each of the five tumor-bearing mice in three groups and five tumor-bearing mice in another group were each given 0.20 mg Holothurin every other day. Five mice without melanoma, and ten mice with melanoma tumors, were also maintained but not given Holothurin. All Holothurin injections were given subcutaneously near the region of tumor implantation in 0.10 ml volumes, and were given over a 13-day period. The survival time was recorded for each mouse, and the mice were weighed in groups of five before tumor implantation and at 5-day intervals during the course of the experiments.

RESULTS

Hemolysis Tests: Minimum concentrations of Holothurin and saponin that produced complete hemolysis were found to be 0.001 mg/ml of Holothurin and 0.25–0.50 mg/ml of saponin indicating that Holothurin was 250 to 500 times more active as a hemolytic agent than saponin.

Holothurin Toxicity in Mice: Holothurin treatment of tumor-bearing white Swiss mice at the level of 0.15 mg/day was lethal at 3 to 8 days with a mean of 4.2 days. See Table 1. Toxicity tests on other

Table 1.

Effects of Holothurin on White Swiss Mice with Sarcoma 180

No. of Mice	Sex	Dose (mg)	Frequency of injection	Survival Time (days)	Body Weight Change 5th day (g)	10th day (g)	15th day (g)
12	F	0	0	18.1 (15–21)	+2.3	+13.0	+25.1
5	F	0.01	daily	19.2 (15–22)	+2.0	+12.7	+27.6
5	F	0.05	daily	17.8 (16–23)	0	+13.8	+33.0
5	F	0.10	daily	16.3 (14–19)	-1.4	+ 8.2	+30.7
5	F	0.10	alternate days	16.8 (15–20)	-1.1	+10.1	+29.4
5	F	0.15	alternate days	26.4 (16–58)	-1.0	+ 2.9	+10.4
5	F	0.15	daily	4.2 (3–8)	died	--	--
5	M	0.20	alternate days	22.2 (10–47)	-1.8	0	0

groups of normal, non-tumor-bearing white Swiss mice indicated that either 0.10 mg/day or 0.15 mg given on alternate days was a safe upper limit for intraperitoneal Holothurin administration. Additionally, 0.30 mg Holothurin in a single injection could be tolerated, but more than this amount in a single injection was lethal. Toxicity tests

on C57-B1-6J mice without B-16 melanoma tumors indicated that these mice could survive single subcutaneous injections of Holothurin as high as 0.60 mg.

Effect of Holothurin on White Swiss Mice with Sarcoma 180: Twelve tumor-bearing mice that were not treated with Holothurin lived for an average of 18.1 days after tumor cell inoculation. These mice gained an average of 25.1 g by the fifteenth day after tumor cell inoculation. This increase in body weight represents the extent of increase in tumor size and ascites fluid accumulation since body weight increase due to growth of the animal during this time would have been negligible. The tumor-bearing animals receiving 0.15 mg Holothurin on alternate days had a mean survival time of 26.4 days representing an increase in survival time of 46%, and a mean weight gain at 15 days of 10.4 g representing a 60 to 70% decrease in tumor growth and ascites fluid accumulation. One of the mice in this high Holothurin dose group had a weight gain of only 5.1 g and was still alive after 58 days. Three of the mice receiving 0.20 mg Holothurin every other day died in less than 12 days probably as a result of Holothurin overdose. Of the other two mice in the 0.20 mg group, one lived for 30 days and the other for more than 47 days and both had negligible weight gain during this period of time indicating complete tumor suppression. The four groups of tumor-bearing mice receiving less than 0.15 mg of Holothurin per injection did not show any significant increase in survival time or decrease in weight gain. See Table 1.

Effects of Holothurin on C57-B1-6J Mice with B-16 Melanoma: Ten C57-B1-6J mice not injected with Holothurin lived for an average time of 29.4 days after B-16 melanoma inoculation with a range of 18 to 43 days. The animals with malignant melanoma tumors decreased in total body weight. Normal, non-tumor-bearing C57-B1-6J mice of comparable age to the tumor-bearing mice all gained weight on the diet and the conditions of this experiment. Measurement of body weight was not a valid indicator of tumor growth or of Holothurin effectiveness, as in the case of mice with Sarcoma 180, because the melanoma tumor grows in a small solid mass and does not induce ascites fluid accumulation. As the Holothurin dosages used here were comparable to the effective doses for white Swiss mice bearing Sarcoma 180 tumors, and were well below the toxic levels of Holothurin for C57-B1-6J mice, none of the animals in this experiment showed any increase in the survival time. See Table 2.

DISCUSSION

The crude extract of Holothurin used here was probably more potent than purified preparations would be. Upon purification, the anti-tumor principle is apparently lost or considerably reduced in con-

Table 2.

Effects of Holothurin on C57-B1-6J Mice with Melanoma

No. of Mice	Sex	Dose (mg)	Frequency of injection	Survival Time (days)	Body Weight Change 5th day (g)	10th day (g)	15th day (g)	20th day (g)
10	M	0	0	29.4 (18-43)	+0.4	-0.7	-0.8	-0.3
5	M	0.05	daily	25.6 (20-42)	-1.1	-3.4	-3.5	-2.5
5	M	0.10	daily	22.7 (19-26)	-4.1	-4.8	-5.4	-4.4
5	M	0.15	daily	24.4 (20-35)	-3.1	-3.5	-4.3	-4.5
5	M	0.20	alternate days	29.6 (25-33)	-2.6	-3.5	-3.6	-3.3

centration (Chanley et al. 1960). One sample of purified Holothurin showed a tenfold-loss in hemolytic activity, and no anti-tumor activity (Nigrelli and Jakowska 1960).

Although the crude extract of Holothurin is effective against various tumors (Nigrelli 1952, and Sullivan, Ladue and Nigrelli 1955), the present study demonstrates that Holothurin is apparently not effective at the same dose levels in differing species of mice. Larionov (1967) suggests that a natural biological product should be more promising as a chemotherapeutic agent than a synthetic compound. The same author has stated that the maximum effective acceptable dosage of an anti-tumor compound is close to the dosage which kills the animal, whereas a decrease in dosage, even slight, leads to a sharp drop in effectiveness. The narrow threshold is seen here in regard to the ineffectiveness of the lower concentrations of Holothurin on the Sarcoma 180 tumors, and the lethal effect of 0.20 mg given over a period of several alternate days to the tumor-bearing mice. Due to the narrow range of effective concentrations of Holothurin in relation to its lethal dose, it is likely that the ineffectiveness of Holothurin in the C57-B1-6J mice bearing B-16 melanomas was a reflection of the tolerance to higher doses of Holothurin in these animals. There is no indication that Holothurin, or any other chemotherapeutic agent, would have differing effects in male and female tumor-bearing mice although profound metabolic differences between male and female rats and mice are well-known (Olmsted 1969). However, the differences seen

in this study could also be due to differences in the injection site or in the types of tumor. While this consideration presents many variables, the Sarcoma 180 tumor grows best in white Swiss mice and the B-16 melanoma grows best in C57-B1-6J mice. Further, it should be noted that the mean survival time of the untreated mice with the two different types of tumor was about the same, i.e., about 3 to 4 weeks after tumor inoculation. The hypothesis is further supported by the finding that Holothurin is many times more effective in causing hemolysis than saponin when living red blood cells are used in the test system.

Other hemolysis experiments similar to those described here have shown that between 0.04 and 0.10 mg of the crude extract of Holothurin would cause complete hemolysis, while 0.08 to 0.10 mg of saponin was required for the same effect (Nigrelli and Jakowska 1960). The apparent 40 to 100-fold discrepancy between the findings of Nigrelli and Jakowska and the findings of the present study could be accounted for by the use of different dilutions of red blood cells, or by differences in the age of red blood cells used, or by species effects. Nigrelli and Jakowska's data suggest that Holothurin is only slightly more effective in causing hemolysis than saponin, while in the present study using red blood cells that were freshly obtained from mice just prior to testing it would appear that Holothurin is some 250 to 500 times more effective than saponin in causing hemolysis. Since a number of studies have shown Holothurin to have profound biological effects in concentrations as low as 0.01 ppm it is not surprising that this biotoxic principle is much more effective than saponin on fresh red blood cells. It would therefore appear that the action of Holothurin involves more than a surface tension lowering effect on living cells.

Because Holothurin is an effective anti-tumor agent at concentrations only slightly lower than the lethal dose, it might be tentatively hypothesized that Holothurin is acting on some process common to all cells, not just tumor cells. However, no studies have been done on the metabolic effects of Holothurin. The studies reported here indicate that the mode of action of Holothurin in retarding tumor growth and prolonging life of tumor-bearing mice is probably different from the action of a surfactant such as saponin. It is likely that the energy requirements of the white Swiss mice with Sarcoma 180 differed from those of the C57-B1-6J mice bearing B-16 melanoma tumors. Other studies from this laboratory on the C57-B1-6J mice with B-16 melanoma tumors have shown that the growth of melanoma tumor occurs at the expense of the anabolic processes of the host mouse. Structural phospholipids synthesized by the tumor were shown to be derived from synthesis in the liver (Terranova, Hardy and Olmsted 1970). Although several experiments have been reported in the literature regarding saponin, none have shown saponin to have any anti-tumor activity *in vivo*. It is likly that saponin destroys cells simply by its

action to lower surface tension starting with the plasma membrane and continuing its action on membranes of other cellular constituents in proportion to the concentration of saponin used. While the action of Holothurin has some yet unknown effect other than, or in addition to, its surfactant effect, it is likely that it causes an inhibition of an active, or energy-dependent, physiological process.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

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DOI: 10.18785/grr.0402.08

A GEOCHEMICAL STUDY OF A MARSH ENVIRONMENT

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INTRODUCTION

The study of the fate and distribution of carbon compounds and their associated trace elements in contemporary environments as well as ancient sediments has added information of importance to geology and the ocean sciences. These recent advances have been spurred on by such interests as the search for deposits of fossil fuels, the control of pollution, the understanding of the origins of life, the analysis of lunar samples, and the hopes for analyses of the surface of Mars.

The organic matter found in Holocene sediments is derived from once living organisms. The complex molecules synthesized by organisms and their degradation products are the object of study of organic geochemistry. After the death of an organism, most of the organic matter in it is utilized by other organisms or oxidized to CO_2. A small amount of the organic matter is not destroyed but is trapped in the top sediment. Biological activity gradually ceases, but slow chemical and physical transformations are continuous. Since the carbon-carbon bond is a strong bond, portions of the original molecules deposited in sediments often survive for long periods of time. Detection of many organic molecules in the concentrations found in nature was impossible before recent improvements in instrumental methods of separation, characterization and quantitation. With the present tools of mass spectrometry and gas chromatography the field of organic geochemistry has undergone a tremendous surge of activity.

The trace metal components of sediments provide a rich area for the study of geochemistry with such a diverse array of mechanisms responsible for their inclusion in the sedimentary environment. The biogenic source of trace metals in sediments is usually assumed but

rarely stimulates a great deal of interest. However, the biogenic component may play a significant role in trace metal fixation in highly productive areas. Because trace metals in a sediment may undergo radical changes in concentration levels with only slight changes in the overall chemistry of the sediment, they should be very sensitive indicators of certain microscale and macroscale chemical and biological factors in sedimentary environments. All organisms rely to a greater or lesser extent upon a constant supply of trace metals for the functioning of their metabolic processes. So profound is the need for certain trace metals in all organisms that they are termed essential trace metals whereas others may form an essential ingredient in the nutrients of only a few organisms. Others may perform no known function or be toxic to most organisms. Even so, plants and animals have the capacity to concentrate most trace metals from their environmental sources. When organisms die, most of the trace metals are released after decay, but a fraction may be retained in the organic debris trapped in the sediments and be preserved as a remnant of the pre-existing life forms. To study the trace metal transfer between sediments and plants, analytical tools of high sensitivity are required to cope with trace concentrations. Fortunately methods and instruments—particularly atomic absorption spectrophotometry—having the required sensitivity are available at modest costs to those interested in conducting trace metal analysis and have greatly facilitated this type of study.

Harbor Island, located approximately 1 mile north of Port Aransas, Texas (Fig. 1), was chosen as an environment to investigate in an organic and trace metal geochemical study. Situated at the head of Aransas Pass Channel, this tidal delta is characterized by a series of salt marshes inundated by tidal creeks and tidal channels. Maximum relief on the island is but 12 feet, but even slight variations in elevation are denoted by the variation of plant species dominating each zone of elevation. The plants are limited to the more hardy herbaceous species which withstand the extended periods of low rainfall and sediment dessication found in the intertidal and supratidal areas. Most of the identified species of plants are also native to the salt marshes of the off-shore islands of Mississippi. The fauna was restricted primarily to members of the lower phyla of the animal kingdom.

Several factors made this island ideally suited for geochemical investigations. The topography reveals rather simple and small scale physiographic processes. The island is protected both from effects of major oceanic disturbances by the barrier islands and from the effects of man by its relative inaccessibility. The minimal number of external parameters was helpful in facilitating the interpretation of the geochemical data collected.

The goal of this study was twofold: 1) chemically to characterize a specific salt marsh, the sediments and associated biota and 2)

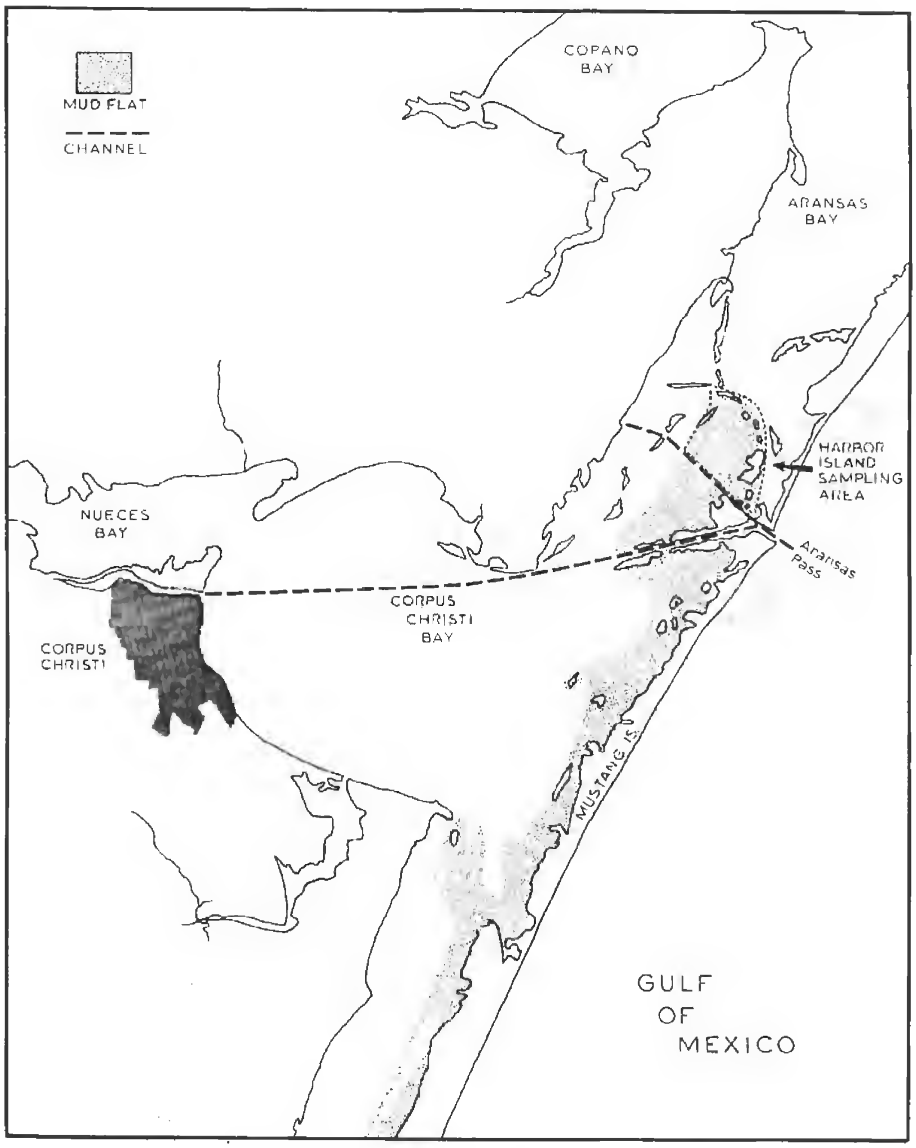

Figure 1. Map of collecting area.

to establish clear relationships between the chemical substances residing in the sediments and similar or identical substances occurring in the biological specimens.

In this particular study it was felt that the hydrocarbons would yield the most significant organic geochemical information. These compounds are ubiquitous but minor components of all organisms. Though their function is not entirely understood, it is known that they are concentrated in the waxy coatings of plants and most likely aid in the protective mechanisms of plants. Among the several classes of biochemical materials, the hydrocarbons exhibit probably the greatest resistance to biological and chemical degradation and therefore may be preferentially concentrated and preserved in sedimentary environments. An extreme variety of specific hydrocarbons occurs naturally in plants and hence the possible combinations and distributions of these hydrocarbons are limitless. The stability and unique distributions of hydrocarbons ranks them as a very important tool in the correlation of biolipids and geolipids.

In choosing the trace metals to be studied, preference was given to those that are known to be essential to all organisms. Those elements fitting this description were copper, zinc, molybdenum, manganese and iron. In addition cobalt known to be essential at least to blue-green algae was included. To monitor the biogenic contribution of non-essential trace metals, nickel, cadmium and lead were also analyzed in the samples. With the diverse functions of these various elements and occurrence at easily measurable levels in most organisms, they should provide useful information about the plant-sediment interplay in a salt marsh.

EXPERIMENTAL

Collection and Handling

A shallow depression outlined by a band of *Batis maritima* (Saltwort) and *Salicornia bigelovii* (Glasswort) was chosen as the site for sediment and plant collection for organic analysis. The sediments were black indicating a reducing environment and contained root mottles and plant debris. Algal mats were forming at the edges of the depression and benthic organisms could be seen as they fed on ditritus present at the surface. Sediment samples chosen for trace metal analysis were surface sediments from three intertidal zones of the island. In addition one subtidal, subsurface sample was taken from the littoral zone of the island. This latter sample was taken to define the trace element distribution in an area not influenced by the marsh plants.

For the organic analysis, seven marsh plants were collected, washed with distilled water and extracted immediately after collec-

tion. After washing the whole plants with distilled water to remove loose debris and epiphytes, the plants were minced in a Waring blender with methanol. The material was filtered and the methanol saved. The minced material was extracted ultrasonically for 15 minutes with 200 ml of chloroform with constant stirring. In addition to these seven plants, seven more species were collected for trace metal analysis (Table 1). Only herbaceous portions of the plants were saved. These

Table 1.

Marsh Plants Analyzed

HYDROCARBONS AND TRACE METALS
Limonium carolinianum (Walt.) Britton (Sea lavender)
Batis maritima L. (Saltwort)
Salicornia bigelovii Torr. (Glasswort)
Lycium carolinianum Walt. (Christmas berry)
Sesuvium maritimum (Walt.) BSP (Sea Purslane)
Oenothera drummondii Hooker (Evening primrose)
Borrichia frutescens (L.) DC. (Sea ox-eyes)
TRACE METALS
Spartina alterniflora Loisel (Cord grass)
Machaeranthera phyllocephala (DC.) Shinners
Spartina patens (Ait.) Muhl. (Salt-grass)
Monanthochloe littoralis Engelm. (Key-grass)
Hedyotis nigricans (Lam.) Fosberg
Avicennia germinans (L.) (Black mangrove)
Distichlis spicata (L.) Greene (Marsh spike-grass)

portions were quickly rinsed in double distilled water and oven dried at 60°C for 48 hrs. Following ashing in a muffle furnace at 450°C for 24 hrs., the samples were leached with 3N HCl and the filtrate over glass fiber filters was saved.

Sediment samples for all analyses were hand collected, and all necessary precautions were taken to eliminate contaminations and to arrest bacterial action. The sediment samples for hydrocarbon analysis were digested with dilute HCl to remove carbonates and washed to remove inorganic salts. Sediments for trace metal analysis were

oven dried at 60°C, weighed, ashed at 450°C digested in 3N HCl, filtered on glass wool and the filtrate saved.

The extracts from plants and sediments were further separated as follows:

Hydrocarbon Separation and Characterization

Each lipid sample (plant and sediment) was saponified by refluxing with 0.5N KOH-MeOH for 1 hour. Nonsaponifiable components were removed by extracting the alkaline solution with benzene. Afterwards, the alkaline solution was acidified with dilute HC1 to pH 3, and the fatty acids were extracted into benzene. Methyl esters of the fatty acids were prepared using BF_3–MeOH (Metcalfe and Schmitz 1961). Silica gel (Woelm, Grade 200, Act. I) was packed beneath 25 ml alumina (Woelm Neutral, Grade 100, Act. I) in a 43 cm X 2.5 cm (o.d.) column. The nonsaponifiable residue was fractionated on the column into four parts: n-hexane fraction contained aliphatic hydrocarbons; benzene fraction contained aromatic hydrocarbons; chloroform–methanol (4:1, v/v) fraction contained alcohols; methanol fraction contained glycerides and the polar lipids.

The aliphatic hydrocarbons were identified and measured by gas chromatography on columns of SE–30, Apiezon L, and FFAP (Varian). Standard hydrocarbons were used to calibrate the Perkin-Elmer 880 gas chromatograph equipped with hydrogen flame ionization detectors. The columns were 8 feet by 1/8 inch o.d. copper tubing. The support was 80/100 mesh Chromosorb G, acid washed, dichlorodimethylsilane treated (Johns Manville). Fatty acid methyl esters were identified using the same instrument but using columns with FFAP, SE–30, and diethylene glycol succinate (DEGS). Linear-log plots of the retention times yielded straight lines for both hydrocarbons and acids and were useful for identification when standards for each carbon number were unavailable. Coinjection of standards were used to clarify some identifications. All hydrocarbon samples were run at programmed temperatures from 100° to 260° at 6°C per minute holding at 265°C. All fatty acid methyl esters were run from 150° to 265° at 6°C per minute holding at 265°C. Mass spectra were obtained with a modified Consolidated Electrodynamics Corp., Model 21–103C mass spectrometer. The spectra were run at 70eV.

Additional sample treatment helped in some identifications. Urea adduction enriched the branched from the nonbranched components. Sulfuric acid and/or bromine–CCl_4 treatment (Morrison and Boyd 1969) identified unsaturated component peaks.

The organic carbon content of the sediment was determined by a combustion technique using a Leco gasometric carbon analyzer.

Trace Metal Separation and Determination

Iron was removed from the sediment filtrate by extraction of the iron-chloro complex from an 8N HCl solution of the total trace metals with isopropyl ether. Separation of all the trace elements of interest from matrix materials except Mo and Fe was effected by adjusting the pH to *ca* 3, adding sufficient ammonium pyrrolidine dithiocarbamate (APDC) to make the final solution 0.5% in APDC and extracting the APDC-metal complexes with methyl isobutyl ketone (MIBK). Molybdenum was extracted from a fresh batch of filtrate by adding KCNS and $SnCl_2$ to make a final 1N HCl solution 2% in both. The molybdenum-CNS complex was extracted with isopropyl ether.

All metals but molybdenum were analyzed using the Perkin-Elmer 303 atomic absorption spectrophotometer. The fuel was acetylene and the oxidant, compressed air. The MIBK solution of cobalt, cadmium, copper, manganese, nickel and zinc and the aqueous solution of iron were aspirated directly using the following wavelength settings (in nm): Cd–229, Co–241, Cu–325, Fe–248, Mn–279, Ni–232, Pb–283 and Zn–214. The color intensity of the Mo–CNS complex was measured at 460 nm on the Beckman Model DU spectrophotometer to determine molybdenum concentrations. Appropriate standards and blanks were prepared for all determinations and any necessary corrections were applied.

RESULTS

Organic

The hydrocarbons from the marsh plants and the blue-green algal mats were assumed to be the main source of the hydrocarbons for the ecosystem studied. Microorganisms were present, but their contribution is taken to be small in an organic-rich sink. Table 2 summarizes the analytical results.

Normal straight-chain hydrocarbons ranging from C15 to C33 were identified in the sediments. Pristane and phytane were present in low concentrations. Phytane was detected only in trace amounts. The branched hydrocarbons were only a very small percentage of the total hydrocarbon fraction. These branched hydrocarbons were almost completely olefinic.

The sediment hydrocarbon distribution was bimodal with maximums at C17 and C29 (Fig. 2). However, the largest concentration of hydrocarbons was in the C27 to C31 range. This reflects the hydrocarbon pattern found in the two prominent contributors to the organic matter, blue-green algae and higher plant life. Normal alkanes isolated from the marsh plants showed an odd-carbon number predomi-

Table 2.

Marsh Plant and Sediment Analytical Analyses

Marine Plant	% lipid / dry wt	% HC / dry wt	% HC / lipid wt	Major Compo-nent
Limonium carolinianum	2.02	0.057	2.8	n-C29
Batis maritima	2.31	0.008	0.37	n-C27
Salicornia bigelovii	2.14	0.005	0.26	n-C31
Lycium carolinianum	3.41	0.085	2.3	n-C29
Sesuvium maritimum	1.91	0.005	0.32	n-C25
Oenothera drummondii	4.72	0.11	2.3	n-C29
Borrichia frutescens	4.91	0.043	0.75	n-C29
Sediment	0.15	0.0011	0.75	n-C29

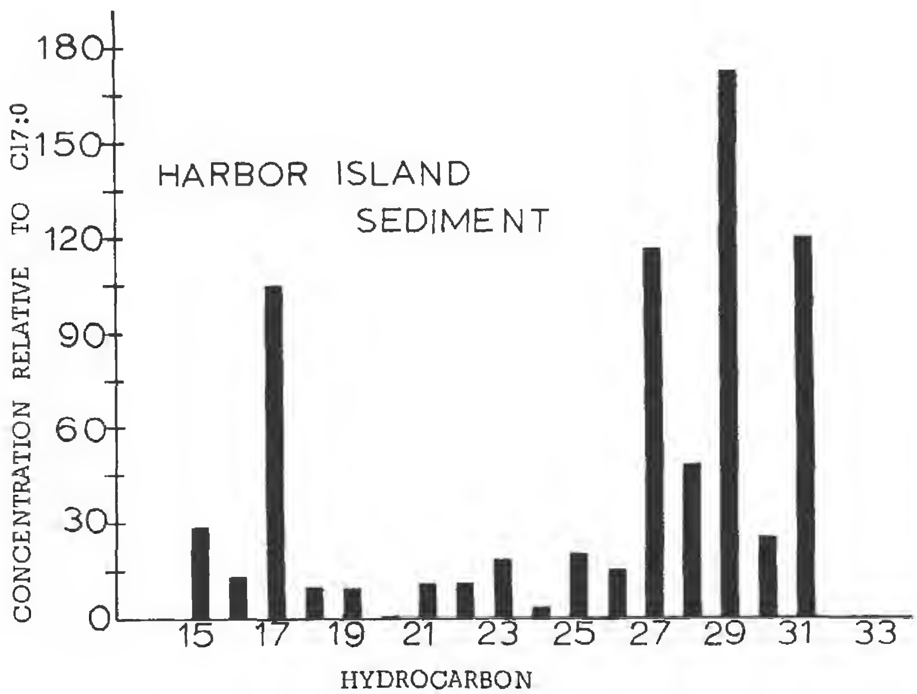

Figure 2. Histogram for normal hydrocarbons of Harbor Island sediments.

nance with C27, C29, and C31 the most prominent alkanes while C17 was the most prominent alkane in blue-green algae.

The urea adducted fraction of the hydrocarbons indicated that the cluster of peaks in the C18 range were not isoprenoid alkanes, but were branched-hydrocarbons with their branching points near the end of the chain. The large number of peaks in the C19 to C20 range were completely absent from the urea adducted fraction indicating that they were more highly branched. These peaks disappeared almost completely after treatment with H_2SO_4 indicating that they were olefinic.

Infrared spectra of urea adducted and urea nonadducted fractions confirmed the evidence that the olefins present in the sediment hydrocarbons are primarily multibranched olefins. In conclusion, the following generalizations can be made about the hydrocarbon results for the sediments analyzed:

(1) All samples exhibited an odd-carbon preference.

(2) A bimodal distribution was exhibited in the hydrocarbon patterns of sediments whose organic matter was derived from both blue-green algae and terrestrial plant sources.

(3) The amount of extracted lipid material in plants was on the order of 25 times as great as that extracted from the sediments.

(4) Pristane and phytane were found in all samples.

Normal alkane distributions in the plants were demonstrated between C13 and C35 but for the most part ranged between C23 and C31. Isoprenoid hydrocarbons, farnesane, pristane, and phytane, were identified, but this fraction represented less than 2% of the total fractions. Branched-chain hydrocarbons, *iso*–C27, C29 and C31, *anteiso*–C26, C28 and C30, were tentatively identified. There were some unidentified peaks in each chromatogram, but those peaks represented less than 10% of the total hydrocarbons. *Borrichia frutescens* contained a large number of branched and olefinic peaks in the C15 to C18 molecular weight range, none of which was identified (approximately 27% of the total hydrocarbons fell in this C15 to C18 range). In all other plants analyzed the lower molecular weight hydrocarbons represented less than 5% of the total weight.

There was a definite odd-carbon preference in every plant sample. The largest component in four of the species was C29. The distributions were slightly different for each species. Gas chromatographic analyses, tabulated in terms of individual normal hydrocarbons from C15 to C33, are presented in Fig. 3.

Olefins have been reported in the hydrocarbons of many plants (Stransky and Streibl 1969), but there was little evidence of olefins

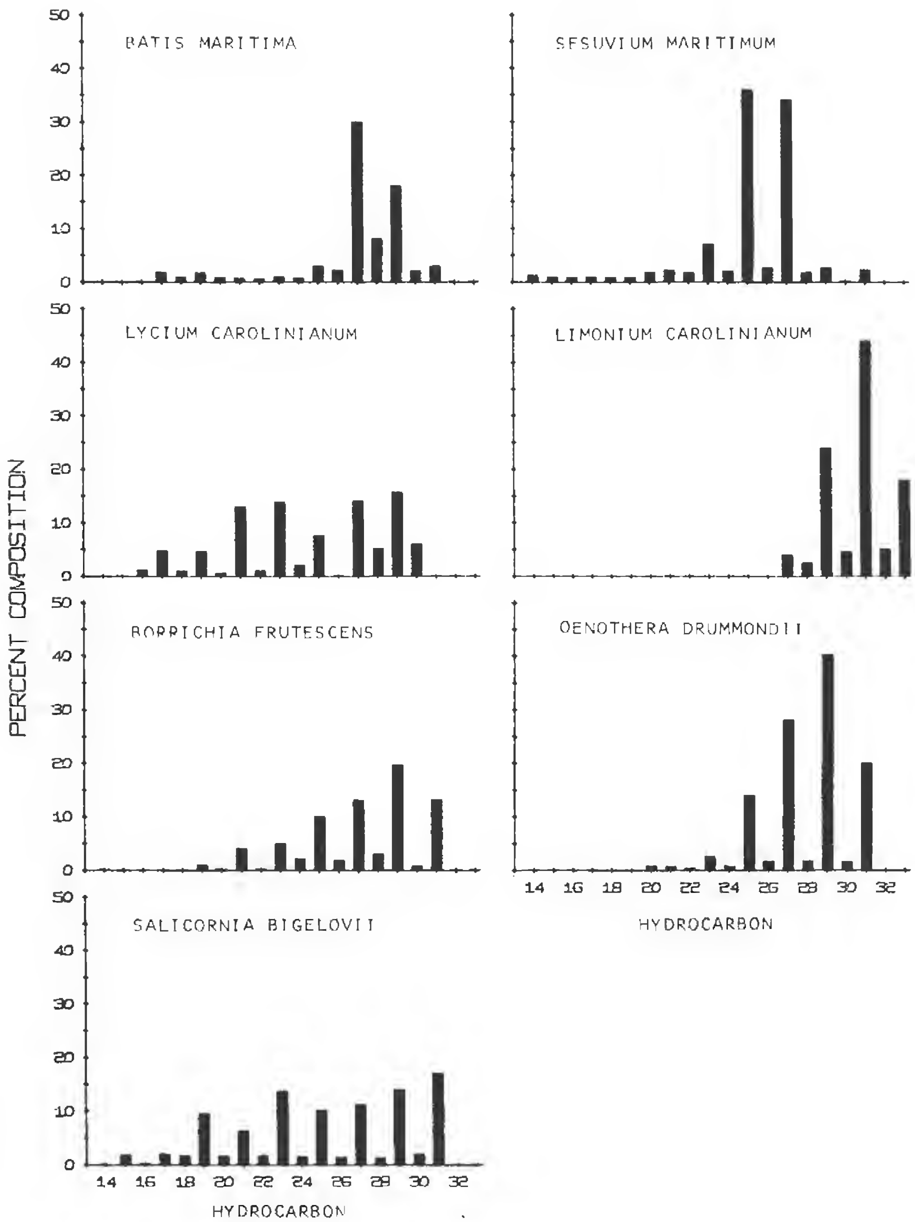

Figure 3. Histograms of normal hydrocarbons in marsh plants.

being present in greater than trace amounts in any sample except *Borrichia frutescens*. Microhydrogenation of olefins in this particular sample yielded normal alkanes. However, some peaks in this sample were not changed by hydrogenation; nor were they enriched in the urea nonadducted fractions. Hence, they were tentatively identified as branched hydrocarbons having their branching points near the end of the carbon chain.

Gas chromatograms are shown for two plants which contained unidentified peaks (Fig. 4). Tentative identification for the *iso*– and *anteiso*–alkanes as was given in Fig. 5 was based on their response to urea adduction, their inertness to H_2SO_4, and the absence of functional groups in the IR spectra. Plots of retention time *vs.* carbon number for the three series, normal alkanes, ABC, and XYZ yields three parallel lines which indicates that the latter series are two distinct, homologous alkane families.

Trace Metals

In the sediments selected for trace metal analysis it was assumed that primary sources of biogenic material were the marsh plants. By choosing intertidal and supratidal sediments a large contribution from blue-green algae was hopefully excluded. A summary of the trace element data obtained from three surface and one subsurface sediments is contained in Table 3. Included are the results of organic carbon determinations. Overall the levels of trace metals are quite low when compared to an "average" sediment from the near-shore area such as provided by Chester (1965). The distribution among the sediments of any one element when compared to another shows similar trends so that it appears that no highly significant variations in trace metal fixations exist among the four sediments. However in inter-sediment comparisons it can be seen that significant differences do exist among the individual sediments, indicating degree rather than type as the more important aspect in investigating the effects responsible for trace metal fixation in these sediments.

The fourteen marsh plants have a trace metal distribution which is shown in Table 4. In Fig. 5 are displayed the ranges of trace metals in the marsh plants and some results of other workers in summarizing available data on terrestrial and on marine plants. Fitting certain characteristics of both groups, it might be expected that the marsh plants would assume some sort of "middle ground". These marsh plants appear to be slightly depleted in most elements except for molybdenum with respect to the terrestrial-marine range. With the principal source of heavy metals coming from the soil solution, it is not surprising from viewing the trace metal array in the sediments that these relatively low levels would be reflected in the biota of the regions.

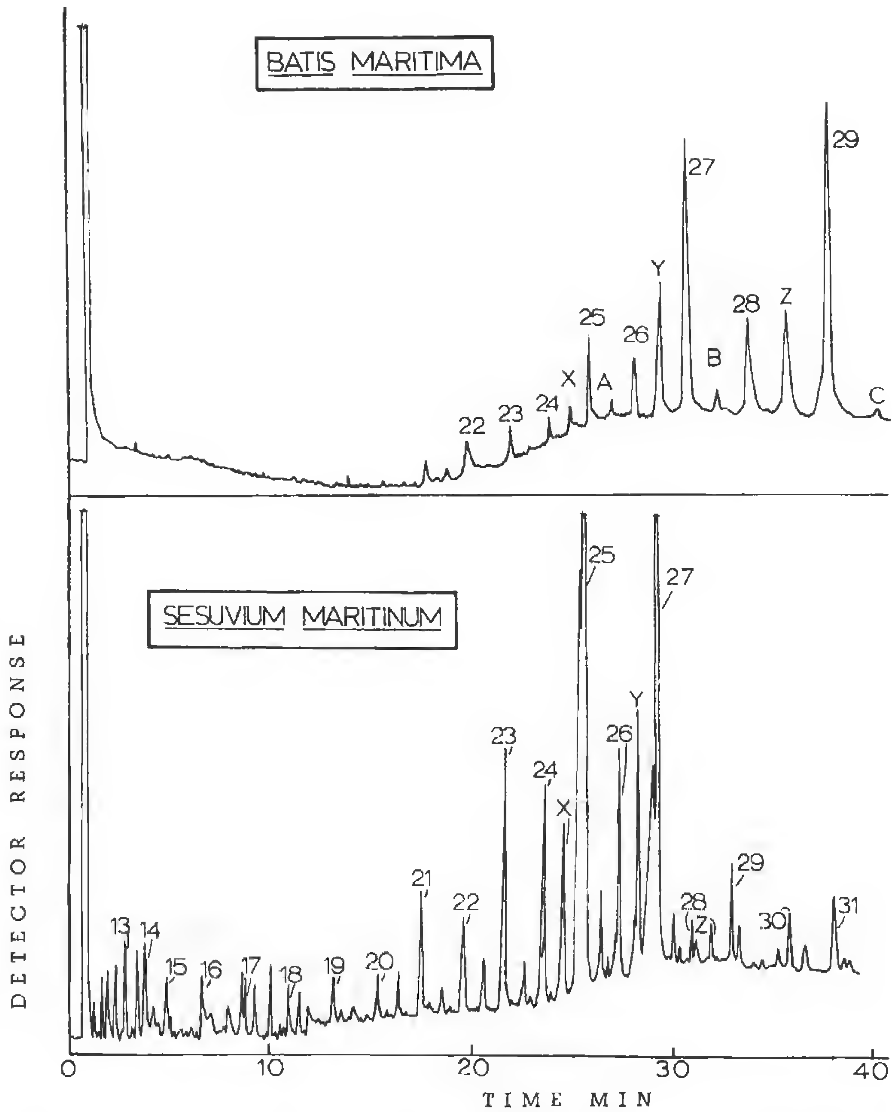

Figure 4. Chromatograms of *Batis maritima* and *Sesuvium maritinum* hydrocarbon extract:

Operating Conditions

Column coating: FFAP
Column dimensions: 150 ft. x 0.02 in

Temperature program: 150°-210° at 4°C/min
Helium flow: 4 cc/min

Key

X-*iso*-C25	**A-*anteiso*-C26**
Y-*iso*-C27	**B-*anteiso*-C28**
Z-*iso*-C29	**C-*anteiso*-C30**

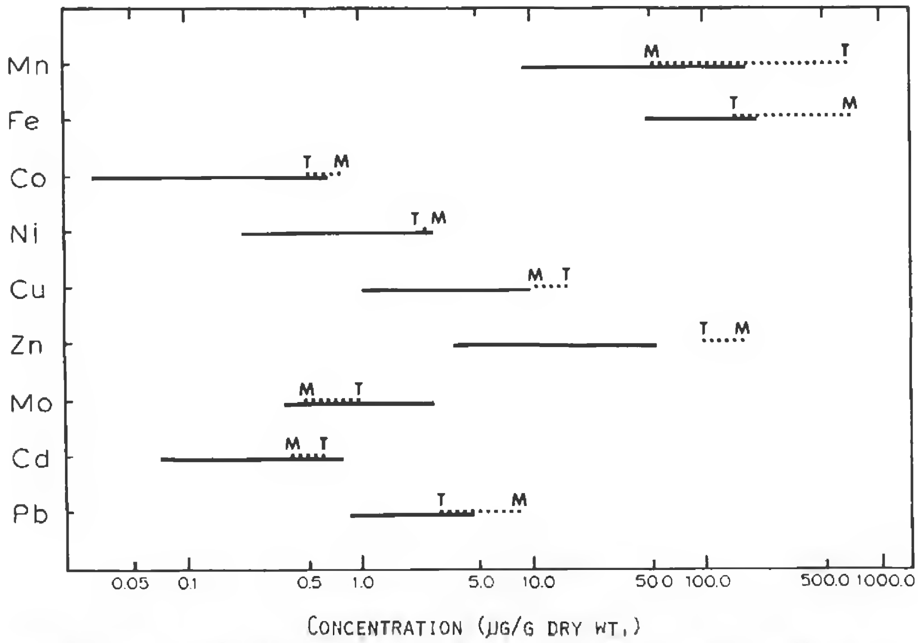

Figure 5. Ranges of trace metals in marsh plants—The range of each metal among the plants is indicated by the solid bar for that metal extending from the minimum value to the maximum value. Also included are bars extending from averages of terrestrial (T) to those of marine (M) plants reported by Bowen (1966).

DISCUSSION

Hydrocarbons

The odd-carbon predominance of the hydrocarbons in the Harbor Island sediments reflected the hydrocarbon composition of the marine plants, in particular the distribution in the C25–C31 range. The large concentration of C17 reflected the blue-green algal contribution to the sediment hydrocarbons (Winters, Parker and Van Baalen 1969, Gelpi et al. 1970). Thus, the correlation between biological and geological lipids was found to exist, the sediments retaining the biological information needed in order to recognize what type of life dominated their surroundings. This correlation between biological and geological hydrocarbons can be extended to include the isoprenoid hydrocarbons. Isoprenoids are abundant in the marine environment (Blumer 1965, Clark and Blumer 1967, Blumer, Mullin and Thomas 1964, Blumer and Thomas 1965). Pristane in marine algae was reported by Clark (1966). Pristane and phytane were found in photosynthetic and nonphotosynthetic bacteria by Han et al. (1968). Isoprenoid hydrocar-

Table 3.

Distribution of Trace Metals in Harbor Island Sediments

Sediment	Mn	Fe	Co	Ni	Cu	Zn	Mo	Cd	Pb	Org C
#1	108	0.96	5.0	10.9	5.2	28	n.d.*	1.11	3.6	0.66
#2	51	0.24	3.0	7.8	4.3	20	n.d.	0.61	9.0	0.31
#3	45	0.31	2.9	6.8	4.6	16	n.d.	0.42	3.4	0.22
#4	62	0.25	2.0	5.0	2.7	14	1.9	0.54	4.8	0.41
Avg. Std. Deviation(%)	11.6	1.9	3.2	5.0	6.9	2.8	-	9.6	6.1	-

Concentrations listed are expressed as μg metal/g dry-weight sediment except for Fe and organic C whose values are listed in wt. %.

The standard deviations for metal analysis by sediment are added and then averaged to arrive at the Average Standard Deviation.

*n.d. - not detected.

Table 4.

Distribution of Trace Metals in Harbor Island Marsh Plants

Plants	Mn	Fe	Co	Ni	Cu	Zn	Mo	Cd	Pb
Salicornia bigelovii	12	140	0.19	1.5	4.3	6.8	0.62	0.46	0.83
Lycium carolinianum	26	73	0.61	0.53	4.0	6.8	1.9	0.07	1.9
Oenothera drummondii	47	91	0.65	1.4	7.1	38	2.5	0.62	2.3
Limonium carolinianum	21	47	0.33	2.6	1.8	18	0.58	0.19	1.2
Batis maritima	27	200	0.27	1.6	3.3	30	0.36	0.13	1.3
Borrichia frutescens	24	99	0.47	1.5	9.4	29	1.1	0.07	3.9
Sesuvium maritimum	15	49	0.13	0.89	2.8	3.4	0.36	0.19	1.3
Spartina alterniflora	41	90	0.14	0.85	2.8	17	1.6	0.35	3.3
Machaeranthera phyllocephala	24	55	0.066	0.88	5.4	50	1.6	0.57	1.6
Spartina patens	11	110	0.029	0.21	1.7	4.8	1.6	0.74	1.8
Monanthochloe littoralis	9.2	120	0.097	1.8	1.0	5.2	0.78	0.18	1.6
Hedyctis nigricans	18	98	0.12	1.5	5.2	42	1.8	0.40	3.0
Avicennia germinans	170	90	0.077	0.85	8.5	12	0.78	0.19	4.2
Distichlis spicata	22	82	0.061	1.2	2.3	20	2.0	0.14	1.8
Average Standard Deviation (%)	3.5	2.0	8.4	3.2	4.1	4.1	7.7	4.3	4.3

Concentrations listed are expressed as μg metal/g dry weight of plant.
The standard deviations for metal analysis by plant are added and then averaged to arrive at the Average Standard Deviation.

bons are found in petroleum and crude oils in very high concentrations (Bendoraitis, Brown and Hepner 1962, Han and Calvin 1969). The presence of only trace amounts of pristane and phytane in Harbor Island sediments indicates lack of pollution from these sources. This simple model should be useful. It could be of economic significance by its use in understanding the origin of fossil fuels. It could be of social significance by its use in understanding the fate of organic matter. With man's environment being polluted at a rapid pace, it is essential that we understand the fate of organic matter whether it be in the geosphere, atmosphere or hydrosphere if we are to gain control over our environment.

Trace Metals

In an attempt to emphasize the fine differences in trace metal levels in the Harbor Island Sediments a plot of trace metal *vs* organic carbon was made and shown in Fig. 6. This selection of X–Y variables was made assuming the percentage organic carbon is a measure of biogenic input to the sediments. The trends and apparent deviations from these trends were observed rather than absolute levels to establish the correlation of organic matter and trace metal levels.

Since a slightly different selection of marsh plants prevail in each sediment area, a semi-quantitative estimate was made of the actual biomass of plant material in a 25-foot radius of the three surface sediments and the ratios of the various plants in those areas revealed the following plant contributors in decreasing order of importance:

Sediment No. 1—*Salicornia bigelovii, Batis maritima, Spartina alterniflora, Lycium carolinianum* (Christmas berry), *Limonium carolinianum, Borrichia frutescens* (Sea ox-eyes) and *Oenothera drummondii.*

Sediment No. 2—*Spartina alterniflora, Avicennia germinans* (Black mangrove), *Borrichia frutescens, Machaeranthera phyllocephala, Monanthochloe littoralis* (Key-grass), *Hedyotis nigricans, Distichlis spicata* (Marsh spike-grass) and *Spartina patens* (Salt-grass).

Sediment No. 3—*Salicornia bigelovii* and *Batis maritima.*

Defining the relationship of individual plants or groups of plants and the sediments for specific heavy metals was, in this limited study, impossible. However, by comparing the plant data to the data in Fig. 6 and observing the sediment-plant association groups some rather interesting information may be gained.

With respect to all elements but molybdenum (not shown in Fig. 6) a relative slump is seen in Sediment No. 4, the subsurface sample with little contribution from marsh plants. Still other effects such as

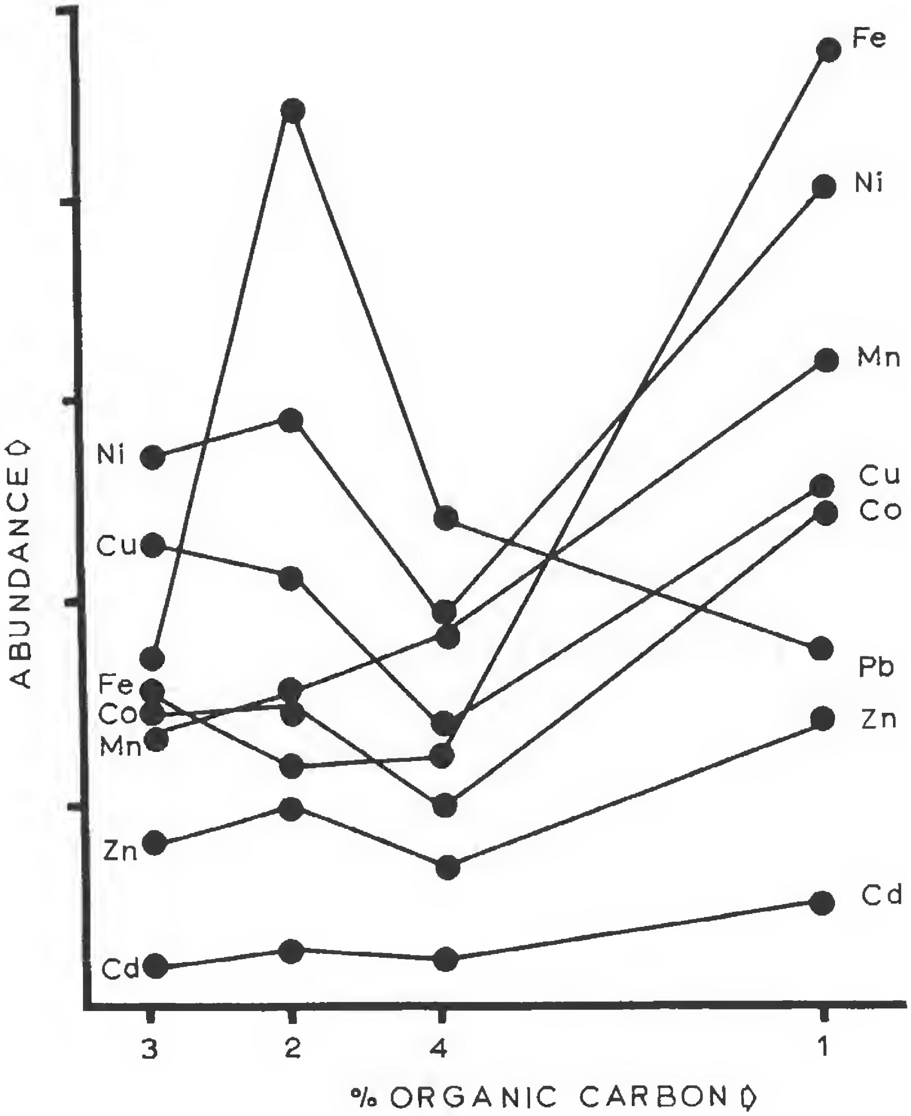

Figure 6. Metals *vs.* organic carbon in Harbor Island sediments—Numbers 1-4 on the organic carbon axis correspond to the Harbor Island soil sediment numbers from Table 3. Both ordinate and abscissa values are on a linear but arbitrary scale. Only the ordinate uses the origin as a value of zero. Organic carbon values: 1—0.66%, 2—0.31%, 3—0.22%, 4—0.41%.

migration of trace elements to the surface and concentration there is a known phenomenon and might account for the surface enrichment. It might be expected that this effect would be noticeable even in the absence of the marsh plants. To a degree the marsh plants still could contribute a significant portion of the trace metals. For any release by dissolution by bacterial action of trace metals beneath the surface of an intertidal or supratidal zone would certainly be impeded by the continual percolation downward of rainwater and receding tidal waters.

Most elements show a positive correlation with organic matter. This previously has been deduced by several workers (Jenne 1968). However, as Jenne pointed out, this contribution by organic matter acts really as a secondary effect. In sediments not having an overwhelming load of organic matter the organic matter with its trace metal load can establish the proper conditions for inclusion of trace metals in ferromanganese oxides. These oxides present in most oxidizing sediments are known to act as very effective trace metal accumulators. The marsh plants may not complete the fixation of trace metals in sediments but at least may start the process by acting as a source and sediment conditioner.

Iron appears quite enriched in Sediments No. 1 and 3 relative to Sediments No. 2 or 4. It seems that any explanation based on a physiographical or geological basis would also alter the distribution of other elements more so than observed. It could very well be that the marsh plants are more active in the transport of this element than the others. Neither Sediment No. 2 nor 4 received any sizeable contribution from *Salicornia bigelovii* or *Batis maritinum* or others having the highest concentrations of iron. Baas Becking and Moore (1959) concluded that the majority of iron in marine sediments exists as complexed iron so that it is possible that these two plants supply substantial amounts of complexed iron in their plant litter.

Though molybdenum is extremely depleted in the surface sediments (Table 3), this metal maintains a normal level in the subsurface sediment. In the marsh plants the levels of molybdenum are the only ranges above and including those predicted from averages of terrestrial and marine plants (Fig. 5). It is known that in surface, oxidizing sediments molybdenum may be lost through its conversion to the soluble molybdate ion whereas in subsurface reducing sediments molybdenum as well as copper, iron, zinc et al. may be retained as their insoluble sulfides. The marsh plants then must speed the depletion of molybdenum from surface samples which after decay of the plants is either leached out of the sediments or transported to reducing layers deeper in the sediments.

Lead is greatly enriched in Sediment No. 2. Some of the plants in this area contain the highest levels of lead though their relative enrichment over those species in other areas could not fully account for

this high level. The possibility of some lead or other metal contamination cannot be entirely dismissed in view of the debris washed in by tidal action.

The marsh plants as a whole have exhibited an ability about as strong as terrestrial and marine plants in accumulating a variety of trace metals from their environment. In some cases the marsh plants may act as sources for trace metal enrichment in the sediments and in other instances, notably molybdenum, as an active depleting agent. The coastal marsh environment widespread along the Gulf and Atlantic coastlines will undoubtedly continue to be a primary target of heavy metal pollution. The varying degrees of enrichment of the various elements both essential and nonessential in marsh plants should make them of value in establishing base-line evaluations of heavy metal inventories in a coastal area.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

An Examination of Legislation for the Protection of the Wetlands of the Atlantic and Gulf Coast States

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DOI: 10.18785/grr.0402.09

AN EXAMINATION OF LEGISLATION FOR THE PROTECTION OF THE WETLANDS OF THE ATLANTIC AND GULF COAST STATES

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INTRODUCTION

The most useful aquatic areas in the world are in serious danger of destruction. The estuaries, where fresh water, land and sea meet in a dynamic and highly productive zone, are today gravely threatened through unwise and unplanned excessive use of their valuable but finite capacities. Estuaries include the coastal zone which is affected by both the run-off of fresh water from the land and the salt water from the sea. This zone includes tidal rivers, marshes, bays and river mouths. The value of these estuarine regions has been well established by biologists. However, this value is fully appreciated by only a handful of people. The intense uses to which the coastal zone is being placed are so expansive, so competitive and potentially so destructive. Much shipping for industrial and military purposes begins and ends in estuaries. The waste products of the industries which crowd the coastal zone and of one-third of the population of this country are daily being poured into these waters. Estuaries are directly linked to suitable conditions needed for the development of three-fourths of the fish and shellfish taken for food production and recreational fishing. In addition, the use of these so important coastal regions is ever increasing by our growing population for aesthetic and recreational purposes.

Each of the above uses is an important human use. However, each of these uses is potentially destructive. Even aesthetic uses, which have heretofore been above reproach, can irretrievably destroy this fragile ecosystem when vast areas are developed for housing projects by dredging and filling in the land. In fact, this action may destroy the very reason why people wish to move to the shore. All of these uses, and others, have developed without sufficient comprehension of their effects and interactions and totally without planning for an optimal balance for present and future human uses. Present and potential human uses involve vast and complicated economic problems, political and geographic difficulties, and grave social and legal complications. It is with the latter, the legal problems of wetlands preservation and utilization, that this paper is concerned.

It is proper that I should here acknowledge the work of Mr. Lionel Eleuterius of the Gulf Coast Research Laboratory who first

visualized the need for a collection and examination of the laws of the various coastal states in regard to the preservation of their wetlands and who personally assembled the raw materials out of which this paper is formed. Furthermore, I should acknowledge Dr. Thomas Lytle, also of the Gulf Coast Research Laboratory, who recommended this project to me and guided my research.

This paper will be divided into several distinct sections. It is initially important that we define just what we are examining; therefore, the first part of this paper will describe what wetlands are and attempt to explain something of the ecology of this region. The next part of the paper will examine the laws of the coastal states to determine what, if anything, they have done to preserve and utilize their wetlands. The last part of the paper will examine what states may do to protect their wetlands, contain a legislative model for a wetlands act, and discuss possible implementation of this proposed legislation.

WHAT ARE WETLANDS?

Wetlands is a general term used to describe the water-land interface, whether ocean and shore or river and bank. However, in this paper we will be more concerned with the ocean-shore interface because of the extreme richness of this particular area and its vulnerability. Wetlands may occur as a dividing fringe along shorelines interposed between permanent dry land and open surface water expanses of rivers, estuaries, etc. They may also exist in another configuration; as rather extensive tracts continuing for hundreds of miles and acres in area.

There are numerous local names by which wetlands are known. Some of these are salt marsh, tidal marsh, marshland, tideland, submerged land, swamp, slough, bog, mud flats, wet meadow, or flood plain. People tend sometimes to use these terms interchangeably, although ecologists differentiate between many of these terms. The following classification system is derived from an extensive analysis of wetlands in Maryland.[1] The classification system briefly describes each type of wetland and outlines very generally the more important physical and ecological characteristics distinguishing each. In examining wetlands, we are concerned with two major distinct groupings: 1.) those wetlands which occur in inland, freshwater areas, and 2.) those which occur in coastal areas and are our especial area of interest.

I. *Inland, freshwater wetlands.*

In this category of freshwater, non-tidal wetlands there are seven types of wetlands included. They are:

[1] Maryland State Planning Department, *Draft Report–Wetlands In Maryland*, January, 1970, p. V3.

1. Seasonally flooded basins and flats
2. Inland fresh meadows
3. Inland shallow fresh marsh
4. Inland open fresh water—ponds, lakes, etc.
5. Shrub swamp—found along sluggish streams.
6. Wooded swamp—often occurs on poorly drained uplands.
7. Bogs—usually waterlogged and having a spongy covering of mosses.

II. *Coastal Wetlands*

This category can be further subdivided into two distinct areas. These are fresh and saline marshes, which are distinguished by differences in shoreline elevation and the consequent varied influence of the tide. This tidal activity partially accounts for the high productivity of the coastal wetland as will be described later. There are seven types of coastal wetland, three of which are in freshwater areas and four of which are in saline areas.[2] They are:

A. Fresh Areas

1. Coastal shallow fresh marsh—average mean high tide may cover this area with up to 6 inches of water.
2. Coastal deep fresh marsh—average mean high tide may cover this area with from 6 inches to 3 feet of water.[3]
3. Coastal open fresh marsh—these are usually more or less enclosed tidal ponds, and vegetation is usually scarce or lacking because of the turbidity of the water due to the tidal cycles and currents which keep sediment and detritus in suspension.

B. Saline Areas

1. Coastal salt meadow—this soil is always waterlogged; but because of its elevation, it is rarely covered by tidal waters.
2. Irregularly flooded salt marsh—the soil in this area is covered by a few inches of water at irregular intervals.
3. Regularly flooded salt marshes—the soil is covered at mean high tide by one-half foot or more of water. This is the area with which we are specifically interested. This area is important as nesting areas for gulls and rails, as feeding areas for herons, as habitat for mussels, snails, and crabs and is used by fish and crustaceans.
4. Sounds and bays—this type consists of submerged land under the open waters of sounds or bays. Vegetation is

[2] *Ibid.*, p. V-7.

[3] The difference in depth of saltwater inundation determines the types of vegetation and animal life found in these areas.

> usually scarce. However, this area is important because it is the habitat of fishes, oysters, mussels, shrimp, clams, crabs, and many other invertebrates upon which these species feed.

This necessarily brief description of the terms used in defining wetlands will serve to illustrate just how minute and complex terminologies can become when dealing with any involved and intricate natural system.

BASIC WETLANDS ECOLOGY

The term ecology has very recently come into vogue. However, the language and techniques of ecology and ecological research are largely unknown to the public. Ecology may be defined as the study of the interrelationships of organisms to one another and to their environment. It is possible to divide a study of an ecological system into two distinct parts: 1.) the structure of the ecosystem itself, including quantity and distribution of plants and animals and the physical characteristics such as temperature, light, pH, salinity, dissolved oxygen, etc.; and 2.) the function of the ecosystem, including the rate and amount of biomass production[4] and the cycling of nutrients within the biotic community. Without a knowledge of these ecological principles and other information, it would be impossible for well-intentioned individuals to formulate sound natural resources management policies. Therefore, I will briefly describe some general principles of ecology and some concepts concerning the marsh ecosystem.

Since tidal marshes are ecological formations resulting from the invasion of shallow water by land vegetation, it would perhaps be best to examine those areas best suited to this invasion. The most obvious place for land vegetation to invade the shallow sea is along the edges of the vast coastal plain which makes up a part of the continental shelf. This coastal plain extends along most of the Eastern and Gulf coasts of the United States but is largely lacking along the Pacific Coast. In early geological history, the present continental shelf was, for the most part, also the coastal plain. Today, the continental land mass is less expansive and much of the former coastal zone is submerged. Some submergence is still occurring, at a rate of about one foot per century; but the coastal area is just about holding its own due to the seaward transport and deposition by rivers of sediments from inland. However, the levee-building activity of the Army Corps of Engineers is diverting this sediment from the coastal zone and actually forcing it out to the edge of the continental shelf where it is lost for human use for all practical purposes. In some coastal areas,

[4] Biomass may be defined as the total quantity at a given time of living organisms of one or more species per unit of space (species biomass), or of all the species in a community (community biomass).

marshes. Among marine species only a relatively few can adjust to the rapid salinity changes which occur with each tide. Those few species that can endure the tidal marsh conditions, however, are relatively free of the kinds of competitors and enemies that harass related species in nearby waters.

As in other ecosystems, the same general relationships and components exist in a tidal marsh. Plants utilize sunlight energy in their growth and reproduction and are the primary producer component of the ecosystem. They are a source of food for grazing animals. These animals in turn furnish food for carnivores. Bacteria and fungi comprise the component which reduces or decomposes the dead organisms to inorganic levels, returning such nutrients as phosphates and nitrates to the marsh system where they are re-used by the plants in the manufacture of more plant tissue. In conjunction with the re-use of the nutrients and the one-way flow and ultimate release of the energy first stored by the plant life, it is necessary to add to this simple structure other natural trends and cycles which affect the marsh ecosystem. The tides redistribute nutrients and sediments throughout the tidal marsh. They also affect the overall primary productivity by decreasing or increasing exposure of the microscopic algae and marsh plants or the quantity of phytoplankton that is favorably exposed to sunlight as the volume of water over the marsh changes.

It has been claimed that "tidal marshes and estuaries . . . are among the most fertile areas in the world in terms of energy, calories, proteins, carbohydrates and vitamins."[5] Ecological studies have shown that "gross income from the best market farms . . . runs as high as $2,000 per acre per year. On a comparative basis, the major marshlands are producing $4,000 worth of nutrients per acre per year."[6] Fertility of estuaries also results from year-round primary production. Wetlands ecosystems tend to maintain a constant rate of production during seasonal environments. For example, marsh grass produces at least two crops per year as compared with wheat which grows only a few months with zero growth for many months. The annual production of a marsh, or an estuary as a whole, may be double or triple that of ordinary agricultural land simply because it produces two or three times as long each year.

Now that we have very briefly examined some basics of marsh ecology and its importance, it is time to turn to the next major area of this paper, an examination of the various coastal states with regard to those laws which have been enacted to protect their wetlands.

[5] Robert L. Dow, *Maine's Coastal Marshlands: Their Values, Present and Future* (Augusta: Maine Department of Sea and Shore Fisheries, 1962), p. 3.

[6] Robert L. Dow, *Economic Yields of Some Maine Coastal Wetlands* (Augusta: Maine Department of Sea and Shore Fisheries, 1966), p. 1.

LEGAL APPROACHES TO THE PROTECTION OF WETLANDS

In this chapter, I shall examine statutes from the states on the Atlantic Coast and on the Gulf Coast of the United States and shall emphasize those which act to protect wetlands. First, I will examine the Federal laws relative to this area; and then, I will examine the laws of the states in geographical order from Maine to Texas.

A. FEDERAL LEGISLATION

The English Common Law has come into all of the United States, with the exception of Louisiana, and has evolved through case interpretation by the Supreme Courts of these various cases. The essential common law principle is that title to soil under navigable waters is in the sovereign except as far as private rights have been acquired in an expressed grant from the original sovereign. During the time of the original thirteen colonies, the tidelands and the submerged lands were under the complete control of the Crown and they were held by the Crown in trust for the people as a whole. The riparian owner has ownership ordinarily only to the mean high water mark.

After the Revolutionary War, the American states succeeded the Crown as Sovereign. The States continued to hold the tidelands and submerged lands in a sovereign capacity in trust for the people subject to the public purposes of navigation, commerce, fishing, boating, recreation and enjoyment free from obstruction and interference.

State ownership, and in some cases private ownership, of tidelands and submerged lands are subject to the paramount right of control by the Federal Government under the U.S. Constitution for commerce and navigation. As stated, all real property was originally in the Sovereign. It was then granted in one way or another to private individuals. There are three types of grants from the Sovereign: 1.) the first, was by the Lords Proprietors; 2.) by the Crown itself up until the time of the Revolutionary War; and 3.) from the Revolutionary War to the present in the form of State Grants.

The States of the Atlantic and the Gulf Coast have absolute title to submerged lands. The state has prima facie title (i.e. it goes into the court with a presumption of title) to the tidelands, i.e., the area between the mean high water mark and the mean low water mark. A claimant to private ownership of tidelands must come into court with a chain of title, tracing his title back to the original grant from the Sovereign. This is sometimes difficult to do due to the destruction of the intervening records. A claimant must produce an original grant which is then presented to the court as a question of law as a construction of that grant.

The Federal Government has jurisdiction over these tidelands, submerged lands and navigable waters under the Navigation and

Commerce Clauses of the Federal Constitution. There is joint or concurrent jurisdiction between the Federal Government and the Government of the particular State over the navigable waters of the United States which are also navigable waters of that particular State. The navigable waters of a State include all of the navigable waters of that State, whereas, the Federal Government only has jurisdiction over a certain percentage of those waters which have been classified, either by the Federal Congress or by some rule and regulation, as being Federal navigable waters. These waters are usually waters that are in continuous connection between different states or between the state and the open ocean.

The other State waters are under the complete jurisdiction of that particular State. The law, as far as the Federal Government is concerned, was relatively stable up until 1947 when after a period of time the U.S. Department of Interior through the U.S. Attorney General's Office began litigation first against the State of California and later involving decisions in 1950 against the States of Texas and Louisiana attempting to take over actual Federal ownership of all tidelands and submerged lands. The decisions of the U.S. Supreme Court in effect completely reversed all prior law and stated that the Federal Government was the absolute owner of these areas. The Congress passed the Submerged Lands Act of 1953 whereby the Federal Government, in effect, abandoned the title to the area lying below the mean high water line and left the actual ownership in the hands of the State as determined by the State law. At the present time, the only interest the Federal Government has in these areas is this easement or servitude on the part of the Federal Government for the control of commerce and navigation which goes up to the mean high water mark. Congress also has an interest, of course, in any of these areas which affect National Defense, international affairs, flood control and electric power production.

Some of these Federal Agencies with various powers of regulation are the Federal Power Commission, U.S. Navy, U.S. Army Corps of Engineers (which has essential control over interstate navigation and the intracoastal waterway), and the U.S. Coast Guard with the enforcement of revenue laws and boating laws.

In 1953, the Federal Government also passed the Outer Continental Shelf Lands Act which stated that the Federal Government had absolute jurisdiction between the outer limits of the state boundary, which is usually taken to be three miles, but in the case of Texas and Florida extends out to three marine leagues (which is ten and a half miles) outside of the state's mainland area. The Federal Government is supreme between the state boundary and the extent of the Continental Shelf, extending out in some areas 120 to 150 miles.

The State jurisdiction over the tidelands, submerged lands, and navigable waters are co-extensive with the Federal Government in-

volving both the state navigable waters and the Federal navigable waters. The State has exclusive jurisdiction over the state navigable waters. Within each State there are a number of agencies and departments that have overlapping jurisdiction, regulation and control of the tidelands and submerged lands.

The focus of the Federal Government with regard to the protection of the wetlands has been directed in two major areas: pollution control and preservation of migratory bird nesting and feeding areas. Both of these approaches may be helpful in protecting marshlands. First, let us examine the role of the Federal Government in pollution control.

The Federal Government entered into the area of water pollution control in 1899 with the enactment of the Rivers and Harbors Act.[7] This statute made it a criminal offense to deposit any refuse matter of any kind or description into any navigable water of the United States. In 1966, the U.S. Supreme Court held that "refuse" was not limited to materials of no value but included any substance, whether or not usable by industrial standards, which has a deleterious effect on navigable waters.[8]

The Oil Pollution Act of 1924 was an enactment to deal with the problem of oil discharges from vessels into coastal waters damaging aquatic life, harbors and dock and recreational facilities.[9] The prohibitions in this Act proved to be quite difficult to police as a practical matter.

The Water Pollution Control Act of 1948 was also the really first modern identifiable Federal program for water pollution control.[10] It stated that the pollution of interstate waters which endangered the health or welfare of persons of another state is to be considered a public nuisance subject to abatement and that the States were recognized to have primary responsibility and the right to control water pollution while the Federal Government had jurisdiction over the nation's interstate waterways and their tributaries.[11] The Surgeon General was directed to coordinate and encourage cooperation among all levels of government involved in pollution control and to engage in joint activities with State and interstate agencies.[12] The Act also encouraged the adoption of uniform State laws and the creation of interstate pollution control compacts.[13] The Surgeon General was authorized to prepare and adopt comprehensive programs to eliminate

[7] Rivers and Harbors Act of 1899, 33 U.S.C. §§401–413 (1899).
[8] *United States* v. *Standard Oil Co.*, 384 U.S. 223 (1966).
[9] Oil Pollution Act, 33 U.S.C. §§431–437 (1924).
[10] Water Pollution Control Act, 62 Stat. 1155, 33 U.S.C. §§466 (1948).
[11] *Ibid.*
[12] *Ibid.*, at §466(b) (1952).
[13] *Ibid.*, at §466(c) (1964).

pollution in waterways and support and aid technical research to devise and perfect methods of treatment of industrial wastes.[14]

In 1956, amendments to the original 1948 Act were passed which provided for a much more intensive and well-organized Federal pollution abatement program than did the earlier law.[15] They emphasized the basic policy that water pollution problems were best solved at the local level. Grants to States and to interstate agencies were authorized for administration of water pollution control programs including comprehensive river basin programs involving control, research, and enforcement. It provided for technical assistance, the encouragement of interstate compacts and uniform State laws, the appointment of a Federal Water Quality Advisory Board, and a cooperative program for the control of pollution from Federal installations.

In 1961, the Federal Water Pollution Control Act Amendments were enacted.[16] These amendments extended Federal pollution abatement authority to all interstate or navigable waters, increased construction grants and authorized research facilities in various parts of the country and the conducting of water quality studies in the Great Lakes. It should also be noted that the amendments transferred the administrative responsibilities for the program from the Surgeon General to the Secretary of Health, Education and Welfare.[17]

In 1965, the Federal Water Quality Act was signed into law.[18] Briefly, this Act provided for the adoption and enforcement of water quality standards for interstate waters and set up the Federal Water Pollution Control Administration in the Department of Health, Education and Welfare. It increased construction grants and authorized research and development grants for preventing discharge of untreated wastes from storm sewers or combination storm-sanitary sewers.

In 1966, the Federal Clean Water Restoration Act became law.[19] This Act provided incentives to the States to adopt water quality standards for pollution control and provided for Federal reimbursement for qualified construction projects commenced at a time when Federal grant funds were not sufficient to pay the full Federal share. The purpose of this provision was to encourage a State prepared to move ahead with sewage treatment plant projects to start building without waiting for a Federal grant. Under this program, if the project is Federally approved, the local governments may advance the Federal share of the project themselves and be reimbursed with funds as they become available. It authorized the use of Federal enforce-

[14] *Ibid.*
[15] Water Pollution Control Act Amendments of 1956, 70 Stat. 499, 33 U.S.C. §466–466(k) (1964).
[16] *Ibid.*
[17] *Ibid.*
[18] Water Quality Act of 1965, 79 Stat. 903 (1965).
[19] Clean Water Restoration Act of 1966, 80 Stat. 1246 (1966).

ment equipment with relation to international boundary waters and transferred responsibility for administration of the Oil Pollution Act to the Secretary of Interior and changed that Act to include inland waters.

In 1970, the Water Quality Improvement Act was enacted.[20] This Act forbade oil discharges into navigable waters, adjoining shorelines and the waters of the contiguous zone and requires a National Contingency Plan for removal of any spills. This Act provides that the owner of a polluting facility can be fined up to eight million dollars for the clean-up costs or more if there is willful negligence or willful misconduct.

The second focus of Federal programs is concerned with migratory wildfowl. The Migratory Bird Treaty Act of 1918 assigned to the Federal Government primary jurisdiction over the protection of migratory birds, including wildfowl. This was followed in 1929 by the Migratory Bird Conservation Act which provided the authority and funds for the establishment of Migratory Bird Refuges. The first waterfowl hunting stamp (at a cost of $1) was required by the Migratory Bird Hunting Stamp Act of 1934. This Act helped finance the refuge program.

The Federal Aid in Wildlife Restoration Act (Pittman-Robertson) of 1937 made it possible for many states to initiate programs of wetlands acquisition and development. In 1949, an amendment to the Hunting Stamp Act raised the price of the "duck stamp" to $2; another in 1958 further increased it to $3. The latter amendment also specified that duck stamp funds be used exclusively for the purchase of waterfowl production areas and suitable areas for migratory bird refuges; also that as much as 40% of a refuge may be opened to hunting of migratory birds.

In spite of these efforts, loss of wetlands continues at an alarming rate. In recognition of the growing problem, Congress in 1961 passed a bill which has become known as the Accelerated Wetlands Acquisition Act (Public Law 87–383, approved Oct. 4, 1961). This Act makes possible the stepped-up purchase of essential wetlands now, while they still exist. In effect, Congress could loan the conservation movement $105 million which, plus the revenues from duck stamp sales, could be used for this purpose. This money is to be used to promote the conservation of migratory waterfowl and to offset or prevent the serious loss of important wetlands and waterfowl habitat essential to the preservation of such waterfowl. At the end of 7 years, 75% of each year's duck stamp revenues must be used for repayment of the loan. The task of this legislation is obvious—to save at least an essential minimum of the nation's wetlands.

[20] Water Quality Improvement Act of 1970, 84 Stat. 91 (1970).

B. STATE LEGISLATION

1. Maine

Maine Revised Statutes Annotated, Title 12, ch. 421, §§4701–4709 (Additional Supp. 1967)

No person, agency or municipality may remove, fill, dredge or drain sanitary sewage into, or otherwise alter any swamp, marsh, bog, beach, flat or other wetland bordering coastal waters, or fill, dredge or drain sanitary sewage into such waters within such area, without filing written notice to do so, with plans, to the municipal officers and the Wetlands Control Board. A public hearing is held after receipt of such notice. After the hearing, a permit is issued if the Wetlands Control Board approves. Approval may be conditioned upon the applicant amending his plans. Approval may be withheld by the municipality or the Board if either body finds the plans damaging to fish life. An appeal is provided for. Anyone violating any provision of this statute is subject to a maximum fine of $100. A continuing violation of this statute may be enjoined.

Maine Revised Statutes Annotated, Title 30, ch. 229, §4001 (Additional Supp. 1967).

Wetlands may be "taken" by a municipality with the consent of the owner and payment of compensation.

Maine Revised Statutes Annotated, Title 30, ch. 229, §3001 (Additional supp. 1967).

Any municipality may receive wetlands as devises or gifts.

2. New Hampshire

Wetlands regulation had a modest beginning in New Hampshire in 1955 when the legislature made it illegal to create land by filling in great ponds—lakes or ponds over 10 acres in size—without permission of the Governor and Council.[21] Before that time, apparently a person could convert the state's water into his own land by the simple expedient of filling it in.

This statute dealt with public inland waters, not wetlands as such and was the extent of any regulatory effort until 1965. Then, in an act regulating sewage disposal systems on islands, it was provided that no one could fill in a marsh bordering on or adjacent to a great pond of the State for building purposes without approval of the sewage dis-

[21] New Hampshire Revised Statutes Annotated 482:41–a to 41–d.

posal system in accordance with local zoning ordinances of the municipality, or in absence of same, the Water Supply and Pollution Control Commission.[22] The emphasis of this statute, though, was on the prevention of pollution and not the preservation of wetlands.

In 1967, New Hampshire got its first full-fledged wetland regulations—three dredge and fill laws. The first prohibited any person, firm or corporation from excavating or dredging any bank, flat, marsh, swamp or lake bed that lies below the natural mean high water mark of any fresh public waters of the state without petitioning the Water Resources Board.[23] The second replaced the 1955 law regulating placing fill in fresh public waters with a more up-to-date version.[24] The third prohibited persons from excavating, removing filling or dredging any bank, flat, marsh or swamp in and adjacent to tidal waters without approval of the New Hampshire Port Authority.[25]

In 1971, Bill No. 228 was introduced into the New Hampshire House of Representatives and dealt with excavating, filling, mining and construction in the inland waters of the state and established an inland wetlands authority to which anyone seeking to alter any of the existing interior wetlands of the state would have to make petition for a permit to do so.[26]

3. MASSACHUSETTS

Massachusetts General Laws ch. 131, §40 (1967) entitled: Protection of Flood Plains.

No person shall remove, fill or dredge any bank, flat, marsh, meadow, or swamp bordering on any inland waters without filing notice of his intention to do so, with plans of the proposed activity, with the local authority and with State departments of public works and natural resources. A public hearing is provided for. The local authority may recommend protective measures in the public interest, which are submitted to the Commissioner of Natural Resources. If the area where the work is to be done is essential to proper flood control, the Commissioner may impose conditions necessary to protect the public interest, which must be complied with. A continuing violation of this section may be enjoined.

Massachusetts General Laws ch. 130, §105 (Additional supp. 1966)

Because of the urgent necessity of protecting coastal wetlands, the Commissioner of Natural Resources was given the power to adopt,

[22] New Hampshire Revised Statutes Annotated 149:4–c.
[23] New Hampshire Revised Statutes Annotated 488–A (1967).
[24] New Hampshire Revised Statutes Annotated 482:41–e to 41–i.
[25] New Hampshire Revised Statutes Annotated 483–A, §1–5.
[26] New Hampshire Revised Statutes Annotated 483–B, §1–26.

amend, modify or repeal orders regulating, restricting or prohibiting dredging, filling, removing or otherwise altering, or polluting coastal wetlands. Violations of the Commissioner's order is punishable by a fine of between $10 and $50 and/or maximum imprisonment of one month.

However, if the Commissioner's order so restricts the use of the property as to deprive the owner of its practical use, a court may decree that the order does not apply to that owner's land. In such a case, the Department of Natural Resources may take the land for the State by eminent domain.

Massachusetts General Laws ch. 40 §8(c) (Additional supp. 1968)

This section empowers a city or town to acquire by gift, purchase, grant, bequest, devise, lease, or otherwise the fee or any lesser interest in wetlands and open spaces. It also empowers a city or town to take land by eminent domain for conservation purposes.

Massachusetts General Laws ch. 132A, §11 (Additional supp. 1968)

The State may reimburse a city or town up to 50% of the cost of acquiring land for conservation purposes pursuant to §8(c) of ch. 40.

Massachusetts General Laws ch. 130, §27A (Additional supp. 1965)

No person shall remove, fill or dredge any bank, flat, marsh, meadow or swamp bordering on coastal waters without filing written notice of his intention to do so with the local licensing authority, the State Department of Public Works, and the Director of Marine Fisheries. Restrictions may be placed on such work and such work must be done subject to these restrictions. Violations of this section are punishable by a maximum fine of $100, imprisonment for not more than 6 months, or both. A continuing violation of this section may be enjoined.

A case concerning this section held that it does not authorize an absolute prohibition against the filling in of a privately owned marshland if the result would be that the owner would be so deprived of the practical uses of his land so as to amount to a taking of his land without compensation.[27]

Whether there had been such a deprivation of the practical uses of the marshland as to be equivalent to a taking without compensation depended upon the uses to which the marshland could be put without violating the statutory prohibition against the marsh. Since the evidence at trial on this issue was lacking, the injunctive decree of the

[27] *Commissioner of Natural Resources* v. *S. Volpe & Co.*, 206 N.E. 2d 666 (Mass. 1965).

trial court was reversed and the case was remanded for additional findings on the above issue.

4. Rhode Island

Rhode Island General Laws Annotated §§2-1-13 to 2-1-17 (Additional supp. 1967)

These acts established a public policy of preserving the coastal wetlands of the State. The Department of Natural Resources may, after public hearing, designate coastal wetlands or parts thereof, the ecology of which shall not be disturbed. This designation will be recorded in the registry of deeds in each city or town where the land is located. The right of appeal is allowed for 2 years after recordation. Provision is made for award of damages.

Rhode Island General Laws Annotated §§11-46.1-1 (Additional supp. 1967)

Anyone who dumps or deposits mud, dirt or rubbish upon, or who excavates and disturbs the ecology of intertidal saltmarshes, without first obtaining a permit therefor issued by the Department of Natural Resources shall be fined for each offense $100: $50 to the State and $50 to the complainant. The Director of Natural Resources shall refuse to issue such a permit if in his judgment the dumping or depositing of mud, dirt or rubbish or excavation would disturb the ecology of intertidal saltmarshes.

5. Connecticut

Conn. Gen. Stat. Ann. Title 25, ch. 473, §26-17a. (1967)

The State Board of Fisheries and Game is empowered to do the following:

(1) Acquire wetlands, or any easements, interests or rights therein, by purchase, exchange, condemnation, gift, devise, lease or otherwise.

(2) Enter into agreements with owners of wetlands to conserve wetlands.

(3) Enter into leases with an option to purchase wetlands, provided:
   a. approval of the Commissioners of Agriculture and Natural Resources is obtained, and
   b. the lease does not exceed 10 years.

(4) Take wetlands by eminent domain.

(5) Secure title to wetlands by paying to a municipality the amount of the municipality's tax liens on such wetlands, where the municipality's property tax on such wetlands is unpaid for 6 years.

Conn. Gen. Stat. Ann. Title 25, ch. 473, §25-10 to §25-17 (1967)

These statutes provide for the dredging of sand and gravel from lands under tidal and coastal waters. This is regulated by the Water Resources Commission, supplemented by a member designated by the Shellfish Commission. Public hearings must be held. Shore erosion, navigation, and living resources must be considered.

Local zoning for marshland protection has been unsuccessfully attempted in Connecticut.[28]

6. New York

Long Island Wetlands Act[29]

This Act permits the State to enter into cooperative agreement with towns, villages, or counties for the purpose of preserving and maintaining wetlands on Long Lsland which have been dedicated for conservation purposes. The State is empowered to provide one-half of the cost of maintaining such areas.

New York Conservation Law, §429a-g (1967)

These sections require the issuance of a permit by the Water Resources Commission before anyone may alter the waters of the State. The Commission may issue the permit subject to conditions upon which the work must be done. The following activities require a permit: altering the channel of a stream, removing materials from a stream, excavating or filling in navigable waters, erecting an impoundment structure, dock or wharf in or across a natural stream or watercourse. A violation of this statute constitutes a misdemeanor, punishable by a maximum fine of $500, maximum imprisonment of 1 year, or both.

New York Public Lands Law, art. 2, §3.5 (Additional supp. 1967)

The Commissioner of General Services may license and regulate the business of taking sand, gravel or other materials in or upon lands under water and may prescribe the terms and conditions under which

[28] *Dooley* v. *Town Zoning Commission,* 157 Conn. 304, 197 A.2d 770 (1964).
[29] New York Conservation Law, §394 (1967).

the same may be taken. After adoption of regulations by the Commissioner, it shall be unlawful to take or remove from lands of the State under water any sand, gravel, or other material, without a license.

New York Public Lands Law, art. 6, §§75-78 (Additional supp. 1967)

Empowers the Commissioner of General Services to grant lands under water to a county, city, town or village for conservation and other purposes.

7. NEW JERSEY

The Wetlands Act of 1970[30]

This Act recognizes the ecological importance of the coastal wetlands, and states that it is necessary to prevent the deterioration and destruction of these lands in order to preserve the ecological balance of the coastal area.

The Act directs the Commissioner of the Department of Environmental Protection to make an inventory and maps of the wetlands. The Act authorizes the Commissioner to make regulations restricting or prohibiting dredging, filling, removing, or otherwise altering or polluting the coastal wetlands. The Act requires the Commissioner to hold a public hearing before adopting any regulations concerning the wetlands.

The Act prohibits any regulated activity from being carried on without a permit from the Department of Environmental Protection. The Commissioner must consider the ecological effect of the work to be performed before issuing a permit. The Act provides that any person having a recorded interest in land affected by the Commissioner's regulations may file a complaint in the Superior Court to determine if the regulations deprive him of the practical use of his land. The Act provides a fine of $1,000 to be levied against violators of the regulations promulgated by the Commissioner, and also makes violators liable for the cost of restoration of the affected coastal wetland to its condition prior to the violation in so far as is possible.

N.J. STAT. ANN. 12:5-3 to 12:5-8 (1914)

The Board of Commerce and Navigation must pass on all plans for development of waterfront which involves the construction or alteration of a dock, wharf, pier, bulkhead, bridge, pipeline, or any

[30] I could find no other citation. In the official legislative copy, all that is said is that it may be cited as the Wetlands Act of 1970.

other similar or dissimilar waterfront development. Public hearings may be held. No provision is made for eminent domain. No reference is made to protection of natural resources.

N.J. STAT. ANN. 13:8A-1 to 13:8A-18 (1961)

This is New Jersey's Green Acres Land Acquisition Act of 1961. The Act provides for purchase of lands for public recreation and conservation of natural resources. A sum of $60 million was made available by a Green Acres Bond referendum. The acquisition program is under the direction of the Commissioner of Conservation and Economic Development. Of the total amount available, $20 million was for the purpose of supporting local acquisition. In addition to fee simple acquisitions, acquisition of conservation easements is permitted.

8. Delaware

Delaware Coastal Zone Act[31]

This Act states that the coastal areas of Delaware are the most critical areas for the future of the State in terms of the quality of life in the State. It, therefore, declared that it is the public policy of the State of Delaware to control the location, extent and type of industrial development in Delaware's coastal area. In so doing, it is thought that the State can better protect the natural environment of its bay and coastal areas and safeguard their use primarily for recreation and tourism. Specifically, this chapter seeks to prohibit entirely the construction of new heavy industry in its coastal areas, which industry is determined to be incompatible with the protection of that natural environment in those areas. While it is the declared public policy of the State to encourage the introduction of new industry into Delaware, the protection of the environment, natural beauty and recreation potential of the State is also of great concern. In order to strike the correct balance between these two policies, careful planning based on a thorough understanding of Delaware's potential and her needs is required. Therefore, control of industrial development other than that of heavy industry in the Coastal Zone of Delaware through a permit system at the State level is called for. It is further determined that offshore bulk product transfer facilities represent a significant danger of pollution of the Coastal Zone and generate pressure for the construction of industrial plants in the Coastal Zone, which construction is declared to be against public policy.

This Act, as seen from the above, is quite a radical departure from the historic and traditional policy of every state to encourage any industry it can to build and operate from that state. Since the Act

[31] DEL. CODE ch. 70, §7001–7014.

is so new, it cannot as yet be determined what economic effect this Act will have on the State of Delaware; but it appears to be a serious and determined effort to protect the coastal zone.

9. MARYLAND

ANN. CODE of MD. §§718-731 (1967 Replacement Vol.)

This Act declares that in many areas of the State much of the wetlands have been lost or despoiled by unregulated dredging, dumping, filling, etc. and that the remaining wetlands of the State are in jeopardy of being lost. It declares that it is the public policy of the State to preserve the wetlands and to prevent their despoliation and destruction. §719 defines "state wetlands" and "private wetlands". §721 declares that it is unlawful for anyone to dredge or fill in State wetlands without a license to do so by the Board of Public Works. Anyone violating the provisions of this section is deemed guilty of a misdemeanor and may be fined not less than $500 and not more than $1,000. Each violation shall be a separate and distinct offense, and in the case of a continuing violation, each day's continuance thereof will be deemed to be a separate and distinct offense. Any land created in violation of this section will be the property of the State.

§723 states that the Secretary of Natural Resources may from time to time promulgate rules and regulations governing dredging, filling, removing or otherwise altering or polluting private wetlands. Provisions are made for a permit to carry out any of the above activities on private wetlands. Appeal may be taken to the Board of Review of the Department of Natural Resources and from there to a circuit court in the county in which the land is located. If the court rules that the restrictions under the Secretary's rules and regulations constitute a taking of land without compensation, the Secretary of Natural Resources may proceed to condemn the land or interests therein and take it by eminent domain.

10. VIRGINIA

Virginia has no specific statutes in the Code relative to coastal wetlands protection. There are some statutes and a constitutional article that do provide some measure of protection to some of the wetlands. Two statutes and the constitutional provision listed below pertaining to ownership of lands are particularly pertinent. The Constitution of Virginia states that:

> The natural oyster beds, rocks and shoals, in the waters of this State shall not be leased, rented or sold but shall be held in trust for the benefit of the people of this State, subject to

> such regulations and restrictions as the General Assembly may prescribe, but the General Assembly may, from time to time, define and determine such natural beds, rocks or shoals by surveys or otherwise.[32]

Some wetlands and shallows are included within the area thus protected.

The Code states that:

> All of the beds of the bays, rivers, creeks and the shores of the sea within the jurisdiction of this Commonwealth, and not conveyed by special grant or compact according to law, shall continue and remain the property of the Commonwealth of Virginia, and may be used as a common by all the people of the State for the purpose of fishing and fowling, and of taking and catching oysters and other shellfish . . .[33]

The Code further states that:

> All unappropriated marsh or meadow lands lying on the Eastern Shore of Virginia, which have remained ungranted, and which have been used as a common by the people of this State, shall continue as such common, and remain ungranted, and no land warrant shall be located upon the same . . .[34]

However, an accurate designation of those lands used as a common has been lost over the years and only now are state historians trying to relocate these long obscured lands from old deeds and grants. This work could take several years. Title 62.1, §62.1–3, at first glance, seems to offer protection to coastal wetlands. Closer reading, however, shows that to a large extent the Marine Resources Commission does not have discretionary power relative to filling or over construction of private docks and landings for non-commercial use. The Commission does not have any authority over dredging by a riparian owner.

Altogether, Virginia's statutory provisions are highly inadequate for protecting the coastal wetlands.

11. North Carolina

The North Carolina Department of Conservation and Development shall pass on all excavations and filling proposals. If any state agency raises an objection to action of the Department, a meeting of a Review Board composed of the Directors of other state agencies may be held. The Review Board may affirm, modify, or overrule the action of the Department of Conservation. Provisions for appeal to the

[32] VA. CONST. art. 175.
[33] CODE of VA. tit. 62, §62–1.
[34] CODE OF VA. tit. 41, §41–81.

courts are provided. No provision is made for taking of any land by eminent domain.[35]

A limited acquisition program is in effect funded by part of the State Motor Vehicle Tax Fund.[36]

12. SOUTH CAROLINA

The State of South Carolina in seeking to protect its coastal wetlands has taken the approach of defining its jurisdiction and ownership of the tidelands, submerged lands and waters located in the coastal region of the State. The State of South Carolina has declared that it has absolute title to Submerged Lands (the area below the mean low water mark) in the navigable waters of the State. The State has prima facie title to Tidelands (marshes) (the area between the mean high water mark and the mean low water mark), in and adjacent to the navigable waters of the State. The State holds the Tidelands, Submerged Lands and Navigable Waters in trust for and subject to public purposes and rights of navigation, commerce, fishing, bathing, recreation or enjoyment, and other public and useful purposes, or such other rights as are incident to public waters at common law, free from obstructions and interference by private persons.

On the basis of this general interpretation of the State's definition of tidelands and tideland ownership, there has arisen a legal conflict concerning which lands are actually owned by the State and held in public trust for the people, and which lands are actually owned and/or operated by private individuals. With the exception of isolated cases brought to settle legal disputes to title of specific acreages of marshlands, there has, up to the present, been little or no effort on the part of the State to inventory on behalf of the people of South Carolina the extent of the State's claim to ownership of lands held in trust. The continued lack of an applied formula concerning legal interpretation of ownership of these tidelands has led to an ever increasing number of conflicts between the State and private individuals. In a pilot project in one of South Carolina's counties, an evaluation of ownership claims has pointed out that approximately 90% of tidelands, marshes, and coastal waterways are now claimed by private individuals. These areas so claimed have in many cases undergone extensive improvements relating to water control and management to provide recreational use and development, channel construction, and dredge and fill operations for private real estate development. The South Carolina Water Resources Commission on behalf of the State has collected and evaluated information relating to the tidelands ownership question. This and additional information is available to the State for consideration in resolving the tideland's ownership question.

[35] 1969 Adv. Legislative Service No. 7, §113–229 (effective January 1, 1970).
[36] N.C. GEN. STAT. ch 105, §446.2 (1967 amended 1969).

§1–357 of the Code of Laws of South Carolina, 1962 embodies the principles expressed above. It states, in part, that the State Budget and Control Board is charged with the complete control, regulation and leasing of all State lands and all public trust properties. For the purpose of leasing oyster and clam rights, it shall use as its agent and advisor the Wildlife Resources Commission and funds derived from the Commission shall be used by the Marine Resources Division of the Wildlife Resources Department for research and management of its marine resources. No person or agency, public or private, will construct or in any manner place upon or within tidelands or submerged lands any pier, wharf, or other structure of any nature or excavate, dig or in any manner create a dock, ditch, canal, or watercourse of any nature within or upon such tidelands and submerged lands or place any material upon or change in any manner the natural conditions of such lands without first obtaining a permit from the Board. Public notice shall be made by the Board of all permits issued.

13. Georgia

An attempt to establish a Coastal Wetland Protective Board failed to pass the 1969 Georgia General Assembly. Otherwise only the usual fish and game laws and water pollution laws are germane to wetland protection.

14. Florida

Chapter 67-393 of the General Acts of 1967

This Act amended the Florida Bulkhead Act of 1957 (Florida Statutes, §253.12 et seq.).

§253.12. Vests title in tidal lands in the trustees of the Internal Improvement Trust Fund. The trustees may sell such lands, provided that they determine that the sale would not adversely affect public interests, including the preservation of fish and other natural resources. Notice of the sale must be published in the county newspaper. If objections are filed to the sale, a public hearing must be held. If it appears as a result of the hearing that the public interest would be adversely affected by the sale, then the trustees must withdraw the land from sale. A biological and an ecological survey of the land to be sold must be made in determining whether the sale of the land would adversely affect the public interest.

§253.122. The Board of County Commissioners of each county or governing body of any municipality, after obtaining a biological and an ecological survey, may locate and fix bulkhead lines. Any extension of land outward into the waters of the county is deemed an interference with navigation and the conservation of natural resources.

§253.123 The removal of sand, rock or earth from the navigable waters of the State and the submerged bottoms thereof lying channelward of bulkhead lines is not permitted. Certain exceptions are provided for.

§253.124. Anyone desiring to add to existing land bordering on the navigable waters of the State must apply for a permit to do so. A permit will be issued only if a biological and an ecological survey reveal that the public interest will not be adversely affected. The permit may be revoked for non-compliance with its terms. Anyone who violates this section is guilty of a misdemeanor and upon conviction shall be fined a maximum of $500, imprisoned for not more than 6 months, or both. The trustees have the authority to require the person to remove the fill.

Zabel v. *Pinellas County Water and Nav. Control Authority*, 171 So.2d 376 (1965), on remand 179 So.2d 370, dealt with §§253.122 and 253.124. In this case the local authority lost in its attempt to prevent owners of bottom land from filling approximately 11.5 acres of land to be used as a trailer park. The court held that denial of permission to fill the land amounted to a taking of property without just compensation, because it was not established that granting the permit would materially and adversely affect the public interest.

Florida Statutes Annotated ch. 375 (Additional supp. 1966)

This chapter, entitled "Outdoor Recreation and Conservation," empowers the trustees of the Internal Improvement Fund to acquire wetlands and floodlands by purchase, lease-purchase agreements, or otherwise, with funds from the Land Acquisition Trust Fund.

15. ALABAMA

The State of Alabama has taken the position, as has South Carolina and other States, that the state does own absolutely the submerged lands or the area lying below the mean low water mark, which would include the navigable waters. They have also taken the position that the State owns the tidelands, the area between the mean high water mark and the mean low water mark. They are in the process of litigation, as in all other states. The claimants are now going into court and are attempting to prove by grants, in their chain of title, that their private ownership extends to the mean low water mark, because this tidelands area is now valuable.

The State has entered into litigation involving cases where the tidelands have been filled up by natural accretion. Other cases involve the action of the water in the reliction, or the washing away, of formerly high and dry lands, or formerly tidelands, that are now completely submerged. Ordinarily where there is accretion or reliction,

the boundary line of the fast land owner changes with this change in the mean high water line.

ALA. CODE tit. 8, §§ 232-252 (1932)

The Director of Conservation is vested with authority to develop State-owned swamplands. These laws are designed to encourage exploitation.

ALA. CODE tit. 38, §§119-122. (1932)

These statutes set forth the right of riparian owners. These authorize and encourage riparian owners to develop lands abutting on tidelands owned by the State by filling and improving these tidelands.

The Department of Conservation is authorized to acquire lands in connection with fish and game programs.

16. Mississippi

MISS. CODE ANN. §§7549.7-01 and 7605-09 (1942)

These sections give Port Commissioners or County Port Authorities, respectively, full jurisdiction and control over lands below mean high tide, including filling and dredging operations. The title to oil and gas remains in the State. These statutes are designed to encourage development of the submerged lands.

At the regular session of the 1972 Mississippi Legislature, a bill was proposed in the House entitled the "Mississippi Coastal Wetlands Protection Act." This Act recognizes that the coastal wetlands are of great ecological importance and states that it is necessary to prevent the deterioration and destruction of these lands in order to preserve the ecological balance in the coastal area. It declared that the remaining coastal wetlands of the State are in jeopardy of being lost or despoiled by unwise and unplanned activities; that such loss or despoliation will adversely affect, if not entirely eliminate, the value of such wetlands as sources of nutrients to finfish, crustacea and shellfish of significant economic value; that such loss or despoliation will destroy the ecological system of such wetlands as habitats for plants and animals of significant economic value and will eliminate or substantially reduce marine commerce, recreation and aesthetic enjoyment; and that such loss or despoliation will, in most cases, disturb the natural ability of tidal wetlands to reduce flood damage and adversely affect the public health and welfare; that such loss or despoliation will substantially reduce the capacity of such wetlands to absorb silt and will thus result in the increased silting of channels and harbor areas to the detriment of free navigation. Therefore, it was declared to be the public policy of the State of Mississippi, taking into account varying

scientific, ecological, economic, developmental, recreational and aesthetic values, to preserve the natural state of coastal wetlands and to prevent the despoliation and destruction of these wetlands.

The Act prohibits any regulated activity from being carried on without a permit. It is the duty of any person proposing to perform any regulated activity to ascertain whether such work affects wetlands.

Any person who violates the provisions of this Act will be civilly liable to the State for the restoration of the affected wetlands to their condition prior to such violation, insofar as restoration is possible. In addition to civil liability under this Act, a violation of this Act is a misdemeanor and will be punished by a fine of not less than $500 and not more than $1,000 or by imprisonment of not more than 30 days, or both. The Mississippi State Legislature enacted an amended "Mississippi Coastal Wetlands Protection Act" during its February 1973 session.

17. LOUISIANA

In addition to general water pollution control legislation and legislation for control of fishing, legislation relative to mineral leasing (oil wells) is the only pertinent legislation in Louisiana.

18. TEXAS

REV. CIV. STAT. TEXAS arts. 4051 through 4056a

These statutes give the Texas Parks and Wildlife Commission management control over marl, sand, gravel and shell deposits in the navigable streams, bays, bayous, and the Gulf of Mexico within the jurisdiction of the State. Prior to issuing dredging permits, the Commission must consider possible damage to oysters, oyster beds and fish.

CONCLUSIONS

Several states have statutory provisions relating to wetland, marsh and submerged lands and flood plains. A general categorization of the legal approaches various states have taken based upon the above examination of these statutes indicates the following:

(1) legislation which enables a state to acquire wetlands or any easement, interest or rights therein by the following means: eminent domain, purchase, exchange, gift, devise, lease, lease with an option to purchase, payment of unpaid tax liens on the land.

(2) legislation which prohibits certain activities in wetlands areas.

(a) many statutes provide that a project which involves filling, dredging, obstructing or altering the course of waters in wetlands areas may not commence without obtaining a permit therefor; any conditions placed upon the work in the permit must be complied with. Many of these statutes provide for fines and imprisonment, and violations are subject to injunction or abatement.

(b) a few statutes prohibit uses of wetlands inconsistent with conservation by zoning wetlands for conservation purposes.

(c) one statute prohibits the use of earth-moving equipment in wetland areas, unless such equipment is registered with the Department of Water Resources.

(3) the Long Island (New York) Wetlands Act is unique. It provides that the State may enter into cooperative agreements with counties to maintain wetlands and may furnish one-half the cost of maintenance.

(4) legislation not directly related to wetlands, but affecting flood plains, has been enacted by some states. Such legislation requires that a county zone its flood plains to prevent encroachment and consequent damages.

I would call special attention to legislation of the following States:

1. Connecticut—wetlands acquisition
2. Florida—sale of tidal lands
3. Maine—regulation of dredging and filling
4. Massachusetts—regulation of dredging and filling
5. New Hampshire—regulation of dredging and filling
6. New York—cooperative management agreements
7. Rhode Island—wetlands zoning and regulation of dredging and filling

Recent court decisions in Massachusetts suggest that a legal basis exists for State regulation of marshland use in instances where private ownership and use rights exist which may be in conflict with the public purpose of protection of marine resources. *Commissioner of Natural Resources* v. *S. Volpe and Co.*, 206 N. E. 2d 666 (Mass. 1965) Regulation, through the police powers of the State, is the most direct legal approach to control of use of wetland, marsh and submerged land. This is short of outright acquisition or control of development rights. Therefore, the significance of the Massachusetts court decision cannot be ignored in analyzing other states' laws and policies which clearly support the doctrine that protection of marine resources is a public purpose.

A LEGISLATIVE PROPOSAL FOR PROTECTION OF THE WETLANDS

An act to provide for the orderly preservation and development of the coastal wetlands; to provide procedures for obtaining permits to alter wetlands; to provide penalties for violation of this act; and for related purposes.

Be it enacted by the legislature of the State of ______________:

SECTION 1. This act is to be known as the "Coastal Wetlands Protection Act" and may be so cited.

SECTION 2. It is declared that much of the coastal wetlands of the State of ______________ have been lost or despoiled by unregulated dredging, dumping, filling and the like activities, and that the remaining coastal wetlands of this State are in jeopardy of being lost or despoiled by these and other activities; that such loss or despoliation will adversely affect, if not entirely eliminate, the value of such wetlands as sources of nutrients to finfish, crustacea and shellfish of significant economic value; that such loss or despoliation will destroy the ecological system of such wetlands as habitats for plants and animals of significant economic value and will eliminate or substantially reduce marine commerce, recreation and aesthetic enjoyment; and that such loss or despoliation will, in most cases, disturb the natural ability of tidal wetlands to reduce flooding and adversely affect the public health and welfare; that such loss or despoliation will substantially reduce the capacity of such wetlands to absorb silt and will thus result in the increase silting of channels and harbor areas to the detriment of free navigation. Therefore, it is declared to be the policy of this State, taking into account varying scientific, ecological, economic, developmental, recreational and aesthetic values, to preserve the natural state of coastal wetlands and to prevent the despoliation and destruction thereof.

SECTION 3. For purposes of this act:

(a) "Coastal wetlands," "tidal wetlands," or "wetlands" shall mean those areas which border on or lie beneath tidal waters, such as but not limited to banks, bogs, salt marsh, swamps, meadows, flats or other lowlands subject to tidal action, including those areas now or formerly connected to tidal waters, and the surface of which is at or below an elevation of one (1) foot above local extreme high water.

(b) "Regulated activity" means any of the following: draining, dredging, excavation or removal of soil, mud, sand, gravel, aggregate of any kind, or rubbish from any wetland or the dumping, filling or depositing thereon of any soil, stones, sand, gravel, mud, aggregate of any kind, rubbish or similar material either directly or otherwise, and the erection of structures, driving of pilings, or placing of obstruc-

tions, whether or not changing the tidal ebb and flow. Notwithstanding the foregoing, "regulated activity" shall not include the construction or maintenance of aids to navigation which are authorized by governmental authority; the accomplishment of emergency decrees of any duly appointed health officer of a municipality acting to protect the public health; conservation of soil, vegetation, water, fish, shellfish and wildlife performed by duly authorized governmental agencies; or trapping, hunting, fishing and shellfishing where otherwise legally permitted.

(c) "Dredging" means the removal or displacement by any means of soil, sand, gravel, shell or other material; whether of intrinsic value or not, from wetlands.

(d) "Filling" means either the displacement of waters by the deposition into wetlands of soil, sand, gravel, shell or other material; or the artificial alteration of water levels by physical structures, drainage ditches or otherwise.

(e) "Person" means any natural person, partnership, joint stock company, unincorporated association or society, or the State and any agency thereof, or municipal or political subdivisions or other corporation of any character whatsoever.

(f) "Commission" shall mean the Natural Resources and Conservation Commission, the director of said commission or his duly authorized representative.

SECTION 4. No regulated activity shall be conducted upon any wetland without a permit. Any person proposing to conduct or cause to be conducted a regulated activity upon any wetland shall file an application for a permit with the commission, in such form and with such information as the commission may prescribe. Such application shall include a detailed description of the proposed work and a map showing the area of wetland directly affected, with the location of the proposed work thereon, together with the names of the owners of record of adjacent land and known claimants of water rights in or adjacent to the wetland of whom the applicant has notice. The commission shall cause a copy of such application to be mailed to the chief administrative officer in the town or towns where the proposed work, or any part thereof, is located, and to the Director of the State Game and Fish Commission, the county attorney of the county or counties in which any part of such proposed work may occur or which may be affected by such work, the district attorney of any such county or counties, the boards of supervisors of any such county or counties, and the Marine Resources and Fisheries Conservation Commission. No sooner than thirty (30) days and not later than sixty (60) days from the receipt of such application, the commission shall hold a public hearing on such application. The following shall be notified of the hearing by mail not less than fifteen (15) days prior to the date set for the hear-

ing: all of those persons and agencies who are entitled to receive a copy of such application in accordance with the terms hereof and all owners of record of adjacent land and known claimants to water rights in or adjacent to the wetlands of whom the applicant has notice. The commission shall cause notice of such hearing to be published at least once not more than thirty (30) days and not fewer than ten (10) days before the date set for the hearing in the newspaper having a general circulation in each county where the proposed work, or any part thereof, is located. All applications and maps and documents relating thereto shall be open for public inspection at the office of the commission. At such hearing any person or persons may appear and be heard.

It shall be the duty of any person proposing to perform any regulated activity, including the performance of any contract with any state agency for dredging, sale or removal of shells, gravel, sand or other such materials, to ascertain whether such work affects wetlands.

SECTION 5. In granting, denying or limiting any permit the commission shall consider the effect of the proposed work with reference to the public health and welfare, marine fisheries, shell-fisheries, wildlife, the protection of life and property from flood, hurricane and other natural disasters, and the public policy set forth in Section 1 of this Act. The commission shall require a bond in an amount and with surety and satisfactory conditions securing to the state compliance with the conditions and limitations set forth in the permit. The commission may suspend or revoke a permit if the commission finds that the applicant has not complied with any of the conditions or limitations set forth in the permit or has exceeded the scope of the work as set forth in the application. The commission may suspend a permit if the applicant fails to comply with the terms and conditions set forth in the application. The commission shall state, upon his record, his findings and reasons for all actions taken pursuant to this section. The commission shall cause notice of any order in issuance, denial, revocation or suspension of a permit to be published in a daily newspaper having a circulation in the county or counties wherein the wetland lies.

SECTION 6. (a) An appeal may be taken by the applicant or any person or corporation, municipal corporation or interested community group other than the applicant who has been aggrieved by such order from the denial, suspension or revocation of a permit or the issuance of a permit or conditional permit within thirty (30) days after publication of such issuance, denial, suspension or revocation of any such permit to the court of any county having jurisdiction over the property which may be affected by any such proposed work authorized by such permit.

If the court finds that the action appealed from is an unreasonable exercise of the police power, it may set aside the order. If the

court so finds that the action appealed from constitutes the equivalent of a taking without compensation, and the land so regulated otherwise meets the interests and objectives of Section 1 of this Act, it may, at the election of the commission, (1) set aside the order or (2) proceed to award damages as provided by Section 9 of this Act.

(b) Such appeal shall be brought by a complaint in writing, stating fully the reasons therefor, with a proper citation, signed by a competent authority, and shall be served at least twelve (12) days before the return date upon the commission and upon all parties having an interest adverse to the appellant. Such appeals shall be brought to the next return day of the court after the filing of such appeal. The commission shall forthwith, after service of notice of any appeal, prepare and file in said court a copy of such portions of the record of the case from which such appeal has been taken as may appear to the commission to be pertinent to such appeal, with such additions as may be claimed by any party of interest to be essential thereto, certified by the commission. The court, upon such appeal in making its determinations as provided in subsection (a) of this section, shall review, upon the record so certified, the proceedings of the commission and examine the question of the legality of the action of the commission and the propriety of said action. If, upon hearing such appeal, it appears to the court that any testimony has been improperly excluded by the commission or that the facts disclosed by the record are insufficient for the equitable disposition of the appeal, it shall refer the case back to the commission to take such evidence as it may direct and report the same to the court, with the commission's finding of fact and conclusions of law. Such appeal shall have precedence in the order of trial.

SECTION 7. In determining the propriety of issuing permits for any regulated activity under this Act, the commission and courts are to interpret broadly the provisions of this Act in favor of the preservation of wetlands as opposed to any alteration of the character of such wetlands, and to favor the best public interest as opposed to private or corporate pecuniary interest.

SECTION 8. The Attorney General, district attorney or county attorney having jurisdiction may institute civil and/or criminal actions or proceedings against any person believed to be in violation of this Act. Such action shall be brought in the court of any county in which the alleged violation occurs or in which property affected by such alleged violation is located in the manner of other proceedings.

SECTION 9. Any person who violates the provisions of this Act shall be civilly liable to the State for the restoration of the affected wetland to its condition prior to such violation, insofar as restoration is possible. The appropriate court shall specify a reasonable time for the completion of restoration.

In addition to civil liability under this Act, a violation of this Act

is a misdemeanor and shall be punished by a fine of not less than Five Hundred Dollars ($500.00) and not more than One Thousand Dollars ($1,000.00) or by imprisonment of not more than thirty (30) days, or both.

In the case of continuing violations, each day shall constitute a separate charge; however, separate violations under this Act need not be severed for trial when an identity of parties and location exists.

SECTION 10. If any clause, sentence, paragraph or part of this Act shall for any reason be adjudged by any court of competent jurisdiction to be invalid, such judgment shall not affect, impair or invalidate the remainder of this Act, but shall be confined in its operation to the clause, sentence, paragraph or part thereof directly involved in the controversy in which judgment shall have been rendered.

SECTION 11. This Act shall take effect and be in force from and after its passage.

Gulf Research Reports

Volume 4 | Issue 2

January 1973

The Seasonal Occurrence and Abundance of Chaetognatha in Mississippi Sound

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DOI: 10.18785/grr.0402.10

THE SEASONAL OCCURRENCE AND ABUNDANCE OF CHAETOGNATHA IN MISSISSIPPI SOUND

by

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INTRODUCTION

The Chaetognatha as "biological indicators" have attracted attention from various fields of oceanography and fisheries biology because various species of Chaetognatha are associated with different water masses, and their distribution and numerical abundance are used to infer biological productivity and movements of water with their inherent temperature, salinity, sediment load pH, and other variables (Legaré and Zoppi 1961, Redfield 1950). The Chaetognatha populations, therefore, tend to fluctuate following the seasonal changes and the influx of water masses from different sources.

The present work is a study of seasonal changes in the numerical abundance of the Chaetognatha species during a yearly cycle in Mississippi Sound. A comparison is made with the seasonal abundance of calanoid copepods, an important zooplankton component, for a possible correlation.

MATERIAL AND METHODS

Samples were collected at one station near the middle of Mississippi Sound at approximately 30° 17′ N and 80° 45′ W. The area receives open Gulf waters through the Dog Keys Pass and brackish water from the Bay of Biloxi.

Plankton samples were collected at monthly intervals with Clarke–Bumpus plankton samplers, equipped with silk bolting nets #2 and #10. The nets were towed 15 min. for each haul, and the amount of water filtered was recorded by means of calibrated flow meters attached to the samplers. Both types of nets were used at the surface and at a depth of 10 ft. which is near the bottom. Occasionally the efficiency of the plankton nets decreased due to large amounts of suspended clay particles, phytoplankton blooms, ctenophores and medusoid coelenterates.

Data on temperature, salinity and transparency were recorded at each sampling. Surface temperatures were taken with a precision mercury thermometer (Fig. 1). Water transparency was recorded by

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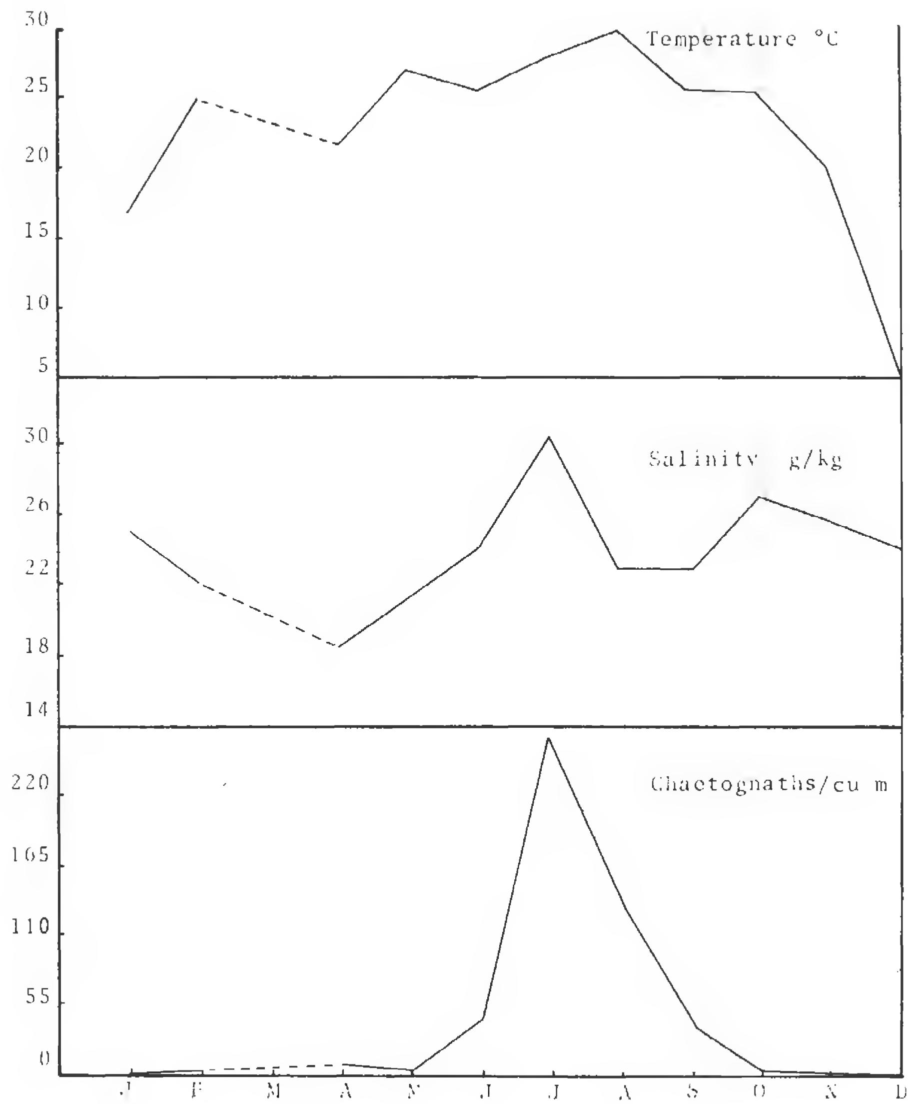

Figure 1. Seasonal variations in temperature, salinity and numerical abundance of chaetognaths in Mississippi Sound from January to December 1965.

means of a Secchi disc. Salinity was determined from hydrometer readings.

The identification of Chaetognatha is difficult when body sizes overlap, and morphological characters vary with age and size. The important characters used in classification were size, extent of collarette, number of hooks, number of anterior and posterior teeth, size and shape of the seminal vesicles, presence or absence of anterior fin, T.C. ratio (the ratio of posterior fin along the trunk to the posterior fins along the caudal segment multiplied by 100) the completeness of the fins, the ventral ganglion and presence or absence of the gut diverticulum (Cf. Grant 1963, Legaré and Zoppi 1961, Pierce 1947, and Thomson 1947).

RESULTS AND DISCUSSIONS

Eight species of Chaetognatha belonging to two genera, *Sagitta* and *Krohnitta*, were identified in the samples (Table 1).

Pierce (1947) reported the occurrence of *Sagitta tenuis, S. hispida, S. enflata, S. helenae* and *Krohnitta pacifica* off the west coast of Florida. All these species were present in our samples. *Sagitta tenuis* and *S. hispida* were most abundant and formed the major part of the chaetognath populations (Tables 1 and 2). Although both of these species are considered warm water neritic forms, they also occur in the Atlantic, but their northern limits have not been determined. *S. tenuis* is found as far north as Delaware Bay and *S. hispida* has been reported to occur as far north as Cape Hatteras in the Atlantic (Deevey 1960). *Sagitta enflata* and *S. bipunctata* were comparatively less abundant. *Sagitta enflata* is an epiplanktonic, warm-water form, but occurs north of Cape Hatteras, where it seems to be a stray form from the Gulf stream. *Sagitta enflata* is abundant in Florida waters (Grant 1963). *Sagitta bipunctata* is an oceanic form and its presence indicates mixed oceanic and neritic waters. Grant (personal communication) has suggested that the Gulf of Mexico chaetognath fauna includes most, if not all, the forms found in the central and equatorial Atlantic. *Sagitta helenae* has restricted distribution and is limited to the waters off the Atlantic coast of the United States and the Gulf of Mexico. *Sagitta hexaptera, S. serratodentata* and *Krohnitta pacifica* were found in fewer number and probably occur as stray forms.

Surface and bottom samples were analyzed separately to see if there was any variation in these shallow depths. A significant numerical abundance was observed only during the summer period (Table 2). In June and August a greater number of organisms occurred in the bottom samples, while in July a comparatively higher number was found in the surface samples. In June and August transparency was low (McIlwain 1968), apparently because of pronounced mixing of

Table 1.

Occurrence, Abundance and Seasonal Variations of Chaetognatha from January to December 1965 in Mississippi Sound

DATE	WATER FILTERED IN CU M	*Sagitta tenuis*	*Sagitta hispida*	*Sagitta enflata*	*Sagitta helenae*	*Sagitta bipunctata*	*Sagitta hexaptera*	*Sagitta serratodentata*	*Krohnitta pacifica*
Jan.	13	–	–	–	–	–	–	–	–
Feb.	43	–	1	–	1	–	–	–	–
Mar.									
Apr.	28	–	186	–	–	–	–	–	–
May	23	–	6	–	2	–	–	–	–
June	23	126	673	–	–	–	6	–	–
July	31	5632	2089	295	–	119	–	–	–
Aug.	24	796	1687	192	17	208	–	5	6
Sept.	22	262	375	9	49	–	–	–	–
Oct.	11	–	2	–	2	–	–	–	–
Nov.	35	1	1	1	–	–	–	–	–
Dec.	51	51	–	–	–	–	–	–	–

Table 2.

Variations in Seasonal Abundance of Chaetognatha Found at Surface and at Bottom, 10 Feet Deep

DATE	NUMBER IN SAMPLES Surface	Bottom	Total
January	0	0	0
February	2	0	2
March			
April	0	186	186
May	8	0	8
June	763	48	811
July	78	8048	8126
August	2501	440	2941
September	195	500	695
October	4	0	4
November	1	1	2
December	0	0	0

Bay and incoming Gulf waters resulting in a turbid condition in the Sound. Such a condition would stir up the normally negatively phototropic plankton which would then be distributed in the water column. In calm waters with greater light penetration chaetognaths, like most plankton forms, would tend to be close to the bottom, which seems true of the samples collected in July (Table 2). During the rest of the year numerical abundance of chaetognaths in the plankton samples was low, and no conclusions could be made about depth distribution.

SEASONAL VARIATIONS

The chaetognath populations indicated marked fluctuations, with changes brought about by the climatological factors and surface drift. The temperature increased from 16.5°C in January to 29.3°C in August (Fig. 1), and decreased rapidly to 12.5°C in December. Salinity showed a rapid decrease from 25.1 g/kg in January to 16.0 g/kg in May 1965. A sharp increase was noticed again beginning in May, reaching a peak of 30.5 g/kg in July. The salinity then decreased, with a sharp decline in August and September 1965.

According to available information, the surface drift in the

northern Gulf of Mexico predominates as a northeast flow from the area east of the Mississippi Delta from March to June and from northeast to southeast from July to August (Drennan 1963).

The chaetognath populations showed a sharp rise and decline following the general pattern of salinity and temperature contours (Fig. 1). Although with warming climatological conditions the reproductive activities of most organisms ensue and the populations increase, the maximum numerical abundance is not noticed at the highest temperature at any one time (Richards 1963, Mulkana 1964). No studies related to the maximum abundance of chaetognath populations at maximum salinity are available, but during the summer, under dry conditions, salinity tends to follow a rising trend and the greatest abundance at the station studied clearly came at a period of high temperature and high salinity.

Life studies of Chaetognatha are now well known. Redfield (1940) has indicated that fluctuations of Chaetognatha will be most marked if the adult does not survive its first breeding, and less pronounced if the adult survives through several breeding seasons. The sharp rise and fall of chaetognath populations in the present study seems to indicate the former condition (Fig. 1). Bigelow and Sears (1939), however, have pointed out that marked occurrence of *S. serratodentata* and periodic occurrence of *S. enflata* in the Cape Cod area appear to depend upon environmental conditions rather than the biology of the reproductive cycle.

Russell (1952), Hardy (1963) and other workers have termed arrow-worms as "biological indicators" because of their usual presence in great abundance when productivity of other organisms is at its maximum. McIlwain (1968) has also shown that the calanoid copepods which form a large part of the zooplankton component in Mississippi Sound were at their maximum during the greatest abundance of Chaetognatha (Table 3).

Other workers attribute the seasonal abundance and fluctuation to hydrographical factors. Redfield (1940) considered that in regions which do not develop permanent eddies, populations of chaetognaths come by immigration from the adjoining areas. In such areas seasonal fluctuations become greater and little time is required to wash away the dense populations. The populations are, therefore, pseudo-endemic and depend upon immigration. The surface drift in Mississippi Sound water changes periodically (Drennan 1963) and perhaps it contributes to the pronounced seasonal fluctuations by immigration.

Table 3.

Comparison of Seasonal Abundance of Chaetognatha and Calanoid Copepods from January to December 1965 in Mississippi Sound

DATE	WATER FILTERED IN CU M	NUMBER OF COPEPODS PER CU M	NUMBER OF CHAETOGNATHS PER CU M
January	13	56	0
February	43	20	.05
March			
April	28	106	6.7
May	23	83	.3
June	23	178	35.3
July	31	385	262
August	24	314	123
September	22	53	31.6
October	11	165	.4
November	38	100	.05
December	51	2	0

REGENERATION

During the course of identifications some specimens were found with a missing head region. Close examination showed the heads were cut off, but the cut ends indicated signs of regeneration. Apparently, some chaetognaths can survive at least for a while after accidental removal of the head region. One other such observation has been reported (Pierce 1947).

Plankton samples collected by Mr. J. Y. Christmas and Mr. C. B. Subrahmanyam in 1966 also showed occasional specimens of *S. enflata* and *Sagitta* sp. with regenerating head regions.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

Studies on the Toxicity of Mirex to the Estuarine Grass Shrimp, *Palaemonetes pugio*

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DOI: 10.18785/grr.0402.11

STUDIES ON THE TOXICITY OF MIREX TO THE ESTUARINE GRASS SHRIMP, *Palaemonetes pugio*

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INTRODUCTION

Limited information exists concerning the effects of the polycyclic chlorinated insecticide Mirex (Dodecachlorooctahydro–1, 3, 4–metheno–2H–cyclobuta [*cd*] pentalene) on non-target organisms. Mirex is the active ingredient in a bait presently being used by the U.S. Department of Agriculture in the Southeastern states to kill the imported fire ant, *Solenopsis saevissima richteri* (Coon and Fleet 1970). The bait consists of 84.7% corn-cob grits, 15% soybean oil, and 0.3% Mirex. The approved application rate is 1.25 lbs. per acre per treatment. The use of this persistent pesticide is causing some concern, particularly in coastal areas dependent on estuarine productivity.

Mirex causes delayed mortality in blue crabs and pink shrimp. After a 96–hr. exposure to 0.1 parts per million Mirex solution, mortality in these animals reached 100% after a 3–week period (Lowe, Davison and Wilson 1970). Mahood et al. (1970) surveyed pesticide residues of blue crabs collected throughout the year in North Carolina, South Carolina, Georgia and Florida and reported that Mirex was second only to DDT in frequency of occurrence. Mirex exposure caused mass mortality and alteration of the developmental stages in the larvae of two crabs, *Rhithropanopeus harrisii* and *Menippe mercenaria* (Bookhout et al. 1972). None exposed to 10 parts per billion Mirex survived the megalops stage. Mortality approached 100% in crawfish in 5 days following a 144–hr. exposure to a 1 ppb Mirex solution (Ludke, Finley and Lusk 1971). Crawfish suffered a high mortality from granular Mirex through leaching and feeding. These crawfish accumulated residues 16,860–fold greater than the surrounding water into which the Mirex had leached.

Lowe et al. (1971) reported the toxicity of Mirex to brown shrimp, *Penaeus aztecus*; pink shrimp, *Penaeus duorarum*; blue crabs, *Callinectes sapidus*; fiddler crabs, *Uca pugilator*, and grass shrimp, *Palaemonetes pugio*. Adult fiddler crabs exposed to levels of Mirex bait equivalent to a field application had 73% mortality within 2 weeks. Juvenile brown shrimp and blue crabs died after exposure to one particle of 0.3% Mirex bait per animal. Using 0.3% bait on *Palaemonetes pugio*, Lowe et al. (1971) induced 70% mortality in 96 hrs.

with one particle of bait per shrimp and 100% mortality in 48 hrs. with five particles per shrimp.

Bodies of grass shrimp killed from exposure to one granule of 0.3% Mirex bait and then fed to blue crabs caused 100% mortality to the crabs within 2 weeks (Lowe et al. 1971). High residues in these crustaceans and mortality in crawfish fed Mirex-exposed *Gambusia* (Ludke, Finley and Lusk 1971) suggest the potential harmful side effects of the fire ant program to natural estuarine communities.

Estuarine grass shrimp (*Palaemonetes*) are common along the Gulf and Atlantic coasts (Faxon 1879, Gunter 1950, Williams 1965, Fleming 1967). These small decapods are found ranging through freshwater areas, brackish estuaries and into inshore saline waters where they are occasionally the predominant animal (Gunter 1950).

In view of the trophic significance of these shrimp, static system bioassays were made to determine the sensitivity of *Palaemonetes pugio* to Mirex in water and to 0.15% Mirex bait granules, since the USDA is continuing the fire ant control program but has plans in the future to substitute 0.15% Mirex bait for the 0.3% bait presently in use (J. I. Lowe 1972, personal communication).

MATERIALS AND METHODS

Grass shrimp, *P. pugio*, were netted in early fall from the dock area of the Gulf Coast Research Laboratory, Ocean Springs, Mississippi. All grass shrimp were held in a stock tank with 20 ppt salinity filtered and aerated sea water prior to the bioassays. Mortality was recorded and dead grass shrimp removed at 12-hr. intervals. Paralyzed shrimp were counted as dead, since they would be subject to abnormal predation in their natural environment. Approximately 10% were ovigerous; the average weight was 0.2 g.

Test solutions consisted of either filtered seawater or distilled water prepared with Rila marine salts, at 20 ppt salinity. Test vessels were 1-gallon glass jars, each containing 1 liter of solution and five grass shrimp. Technical grade Mirex was prepared in 0.1% acetone solution and serially diluted for experiments. The Mirex bait used was obtained from the USDA distribution center in Harrison County, Mississippi and was produced by Allied Chemical Company, Morristown, N. J. Solutions were constantly aerated through glass disposable pipettes. All tests were run at room temperatures of 20$\pm$ 1°C.

Experimental procedures included the determination of the toxicity to grass shrimp of Mirex leached from bait granules (0.15% active ingredient) in water and through exposure to various concentrations of technical Mirex solution.

EXPERIMENTS AND RESULTS

Toxicity of Technical Grade Mirex

Samples of five shrimp were placed in each jar for three sets of nine jars with concentrations of .01 ppm, .1 ppm and 1 ppm Mirex. Samples of fifteen individuals were exposed for 48, 96, and 144 hrs. at each concentration and were then transferred to clean sea water. Controls were set up with an equivalent amount of acetone, but had no mortality throughout the test period. Rostrum–telson length of the shrimp averaged 26 mm.

Mortality began between 24 and 72 hrs. after the beginning of exposures to 1 ppm and .01 ppm respectively, with .1 ppm being intermediate in time to beginning of mortality. Exposure for 48 hrs. to .01 ppm caused 40% mortality during a 12–day period, including exposure time. A 100% mortality occurred in 6 days following a 96–hr. exposure to .1 ppm, and total death prevailed during a 96–hr. exposure to 1 ppm (Table 1). Symptoms exhibited by shrimp prior to death were irritability, uncoordinated movement, loss of equilibrium and spasmodic paralysis.

Toxicity from Mirex Granules

Juvenile (10–20 mm rostrum–telson length, avg. 15mm) and adult (avg. length 26 mm) *Palaemonetes pugio* were exposed to vary-

Table 1.

Percentage Mortality of *Palaemonetes Pugio* (N = 15, avg. length 26 mm) after initiation of exposure to various concentrations of technical Mirex

Mirex concentration	Exposure time (hours)	% Paralysis or death	Days after exposure initiation
.01 ppm	48	40%	12
.01 ppm	96	60%	12
.01 ppm	144	83%	12
0.1 ppm	48	91%	10
0.1 ppm	96	100%	10
0.1 ppm	132	100%	5.5
1 ppm	48	100%	5
1 ppm	96	100%	4
0 ppm	0	0%	12

Table 2.

Percentage Mortality of Grass Shrimp
(juveniles and adults during different exposure times to varying amounts of Mirex bait—0.15% active ingredient)

Granules per shrimp	Length (rostrum-telson)	Days of exposure	Paralysis or death	N
1	20-35 mm	10	43%	30
2	10-20 mm*	8	80%	15
2	20-35 mm	8	50%	15
5	10-20 mm*	8	100%	15
5	20-35 mm	8	67%	15
0	10-20 mm*	8	0%	10
0	20-35 mm	10	0%	15

* Juveniles, avg length = 15 mm
Adult avg length = 26 mm

ing amounts of 0.15% active ingredient Mirex bait (Table 2). Jars were set up as described above, and five to twenty-five granules of bait (avg. wt. = per granule of 1.2 mg) were added to each jar, equalling one to five granules per individual.

Exposure to one granule caused 43% mortality in 10 days to adult shrimp, two granules induced 50% mortality in 8 days, and five granules 67% mortality in 8 days. Juveniles had 80% mortality during an 8–day exposure to two granules, and 100% mortality during an 8–day exposure to five granules of 0.15% Mirex bait. Mortality began 36 hrs. after beginning of exposure. There was no mortality in the controls.

DISCUSSION AND CONCLUSION

Grass shrimp were found to be fairly sensitive to Mirex through direct and indirect exposure. Mortality increased with time and Mirex concentration and appeared to be correlated inversely with animal size. Exposure to all concentrations (.01 ppm–1 ppm) caused *Palaemonetes pugio* to suffer continuous delayed mortality for an extended period of time after the end of the exposure period (Fig. 1). Mortalities from exposure to technical Mirex solutions ranged from 40% in 12 days from a 48–hr. exposure to .01 ppm, to 100% during a 96–hr. exposure to 1 ppm.

Lowe, Davison and Wilson (1970) demonstrated that crabs suf-

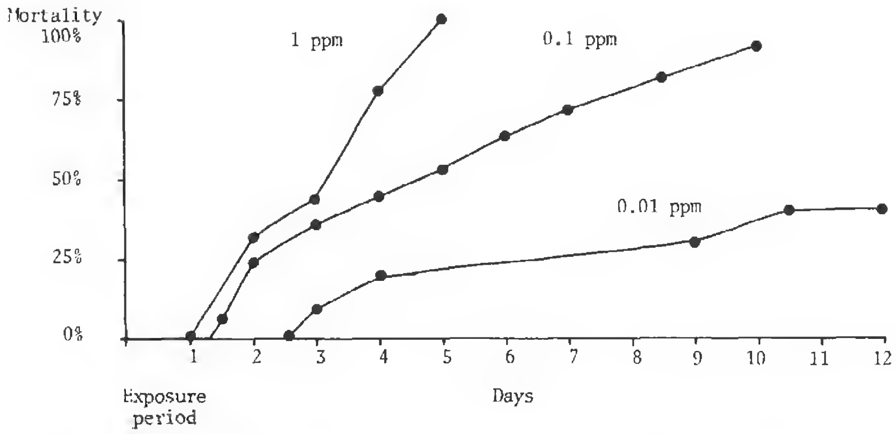

Figure 1. Mortality in grass shrimp caused by a 48-hour exposure to 1 ppm, 0.1 ppm and 0.01 ppm Mirex solutions. Mortality continued well after the end of the exposure period.

fered mortality in clean water after a 96–hr. Mirex exposure. This delayed continuous mortality was also found in crawfish (Ludke, Finley and Lusk 1971) and penaeid shrimp (Lowe, Davison and Wilson 1970).

Extensive mortality occurred in test populations exposed to 0.15% Mirex bait. Exposure to fewer granules decreased the amount of mortality in a given time period. Though mortality was not as great or as rapid as in tests using 0.3% bait on *P. pugio* (Lowe et al. 1971), it appears that significant toxicity is exhibited by the 0.15% Mirex fire ant bait in spite of its reduction in insecticide content.

Water contamination by chlorinated hydrocarbon insecticides through runoff from treated areas in Mississippi (Finley, Ferguson and Ludke 1970), the resistance of Mirex to degradation, and its tendency to move into water by leaching would indicate the high probability of contamination in treated watersheds. Upon reaching Gulf coastal areas (with possible mortality to fresh water shrimp on the way) Mirex-contaminated water could prove destructive to grass shrimp populations since their habitat is associated with estuarine shorelines. The abundance of grass shrimp in coastal shallows (Gunter 1950) indicates their ecological significance.

Mirex-induced mortality in estuarine *Palaemonetes* could prove detrimental to the estuarine ecosystem. This might affect the Gulf's commercial fisheries, since estuaries are the nurseries of many economically important marine animals and estuarine species make up about 97.5% of the total commercial fisheries catch of the Gulf States (Gunter 1967).

In addition, the toxicity of Mirex through trophic levels (Ludke, Finley and Lusk 1971, Lowe et al. 1971), its persistence in the tissues of fish (Lowe, Davison and Wilson 1970) and the usually high toxicity of chlorinated hydrocarbons to copepods, shrimp and crabs (Butler 1964) should be considered in evaluating the potential importance of Mirex as a pollutant in the estuarine ecosystem. The present indications are that it is extremely harmful to crustaceans of all kinds.

ACKNOWLEDGEMENTS

I would like to thank W. David Burke, Dr. Gordon Gunter and other personnel of the Gulf Coast Research Laboratory, Ocean Springs, Mississippi for their aid and assistance. Doctor Gunter identified the shrimp. The author is currently an undergraduate at Harvard University. This work was done at the Gulf Coast Research Laboratory in the summer of 1972.

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

A Study on the Growth Rate of Brown Shrimp (*Penaeus aztecus aztecus* Ives, 1891) from the Coasts of Veracruz and Tamaulipas, Mexico

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DOI: 10.18785/grr.0402.12

A STUDY ON THE GROWTH RATE OF BROWN SHRIMP (*Penaeus aztecus aztecus* IVES, 1891) FROM THE COASTS OF VERACRUZ AND TAMAULIPAS, MEXICO

by

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EXTRACTO

Se hizo un estudio biométrico y del crecimiento individual promedio del camarón café (*Penaeus aztecus aztecus* Ives, 1891). Las muestras se tomaron en las empaca doras de Tampico, Mexico desde junio de 1967 hasta marzo de 1969, y una muestra complementaria hecha en julio de 1971. Los resultados del análisis consisten en regresiones logarítmicas que establecen las relaciones longitud abdominal–longitud total, y longitud–peso para cada sexo y para toda la muestra noblacional en conjunto. Con los datos mensuales de frecuencia de tamaños se determinaron las clases de edad mediante el uso del papel de probabilidad y posteriormente se hizo el adjuste de los datos resultantes, en longitud y peso, al modelo de crecimiento de von Bertalanffy.

INTRODUCTION

The present study was undertaken with the purpose of getting the proper basis for exploiting brown shrimp resources in a rational manner, by introducing control regulations of fishing activities. The growth rate models are necessary for the other parameters of population dynamics of the stocks of this species, whose annual catch, Osborn, Maghan and Drummond (1969), averages 54 million pounds of tail weight, representing 52% of the total shrimp caught in the Gulf of Mexico. This shows that *Penaeus aztecus aztecus* is the most important of shrimp species exploited in this region. Nevertheless, the brown shrimp is the least well known of the three most common species.

The growth rate was determined by fitting the von Bertalanffy growth curve to offshore populations, on which according to Cook and Lindner (1970), there are no published data, although an unsuccessful attempt was made by Klima (1964). Published data are only from inshore waters (Williams 1955, Loesch 1965, Joyce and St. Amant et al., from Cook and Lindner 1970).

Statistical calculations of length-weight and total length-tail

length ratios were required before available raw data could be used in growth analyses. Tesch (1968), points out that age data, along with length and weight measurements represent the basis for information on growth, composition of stocks, maturity age, life span, mortality and production.

ACKNOWLEDGEMENTS

The writer feels deeply indebted to Miss Rocío González for her aid in the translation of this paper into English. I would like also to thank René Márquez, formerly jefe de la Estación de Biología Pesquera de Tampico, who provided access to the data studied here. The final revision of the manuscript was made by Dr. Gordon Gunter and Mr. J. Y. Christmas. I appreciate very much their time invested on the subject and the corrections made to this paper.

MATERIALS AND METHODS

The original information consists of samplings made in canneries, where offshore shrimp are landed in Tampico, Mexico. The samplings were made by biologist Jesús Macías and an assistant, Mr. Francisco Robles, both from the Estación de Biología Pesquera, in that port. The frequency of samplings was twice or thrice a week from June 1967 until March 1969 and consisted of abdominal length records, later grouped to give them monthly representation by means of size–frequency curves with 3 mm intervals for each sex.

The resultant length-frequency curves often show polymodal distributions, and by using probability paper and Cassie's method (1954), it was possible to locate the overlapping values of adjacent modal groups, such as in Fig. 1 where one analyzed month is shown as an example. The mean values gotten for each month were considered as age classes; in such a way a series of data was obtained, every one corresponding to the medium size of the respective generations presented in each monthly sample, averaged in order to fit von Bertalanffy's growth model.

To complete the von Bertalanffy growth model it was first necessary to know the corresponding total length of the original tail length data; consequently, a new sampling was made in July 1971, consisting of total length, tail length, and weight data of five hundred individuals of both sexes. Analyses of these data as logarithmic regressions of the form $Y=aX^b$ gave constants to establish the relationship between both variables and at the same time gave the necessary information on the growth constants not only in terms of length but also in weight.

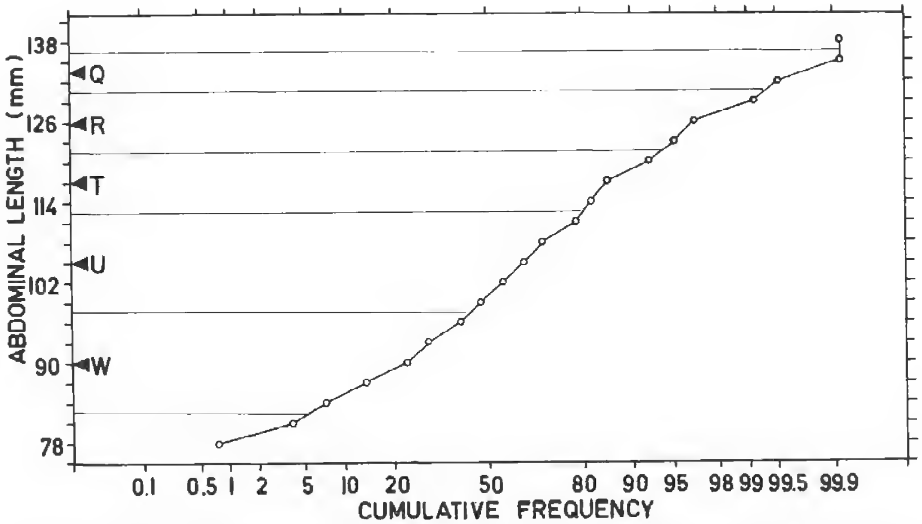

Figure 1. Size-frequency of tail length of brown shrimp plotted on probability paper. The data are from females sampled in January 1969.

RESULTS

Biometric analysis. The biometric study of samples was undertaken first for each sex separately, and later with both sexes together, in order to obtain the parameters of the analyzed population as a whole.

Figure 2 shows the scatter diagram of the total length–tail length data and the regression line describing the relationship between 251 pairs of values in males. The correlation coefficient was r =0.999 and the equation with the constants is $Y = 2.05X^{0.932}$; it corresponds to an almost straight line which is not rare in the relatively narrow range of sizes of the sampled shrimps.

In the case of females (Fig. 3), a straighter relationship than in males can be shown, getting the same value for the correlation factor, as in the former analysis, of r = 0.999. The values of constants found are as follows: a = 1.531 and b = 1.001. The number of females exmined was 247.

After the data for each sex were studied, the regression constants for the whole population were calculated. The results are shown in Fig. 4. They indicate that the parameters found are values lying between those of the regressions formerly analyzed. They are as follows: r = 0.998; a = 1.621; and b = 0.987.

The length–weight ratios were determined in the way mentioned before, and for the same reason the results are analogous. The results

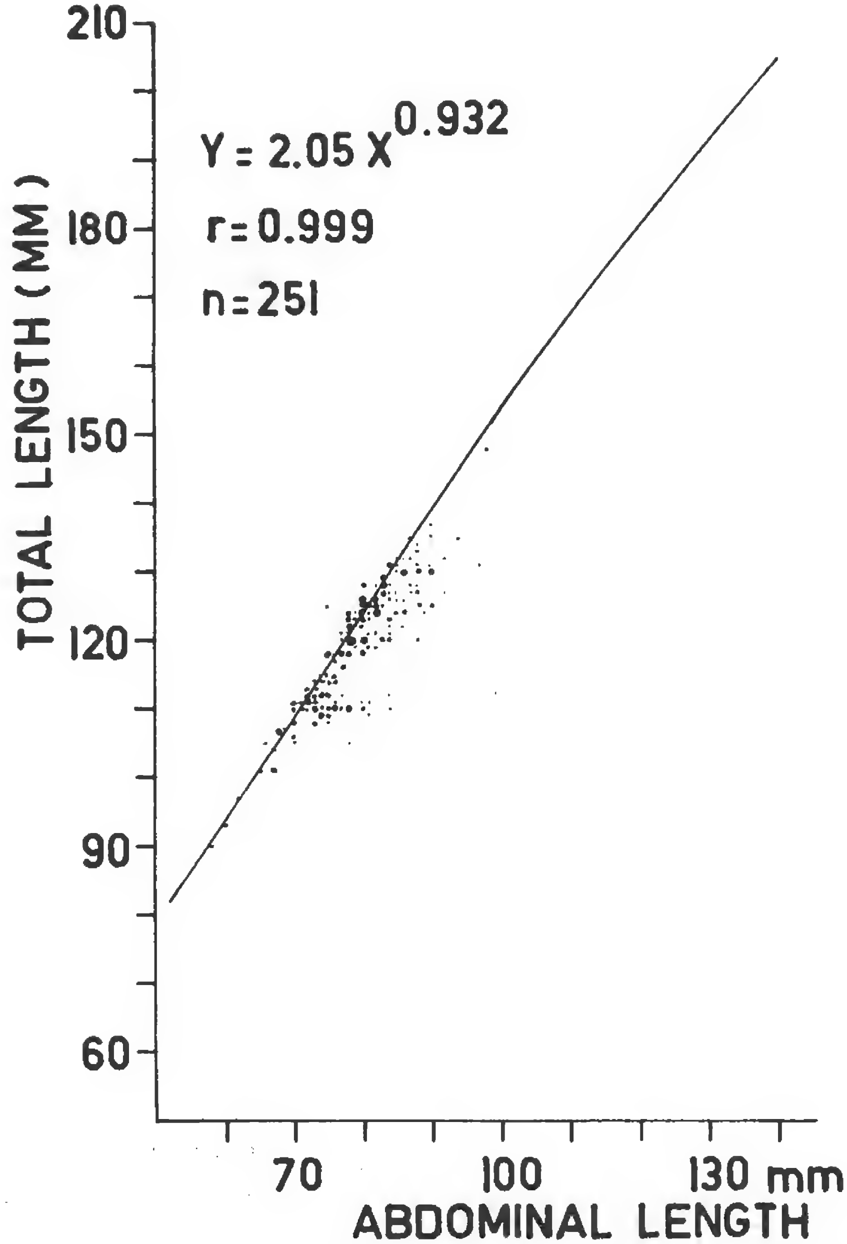

Figure 2. Regression analysis of total length-abdominal length in males of brown shrimp.

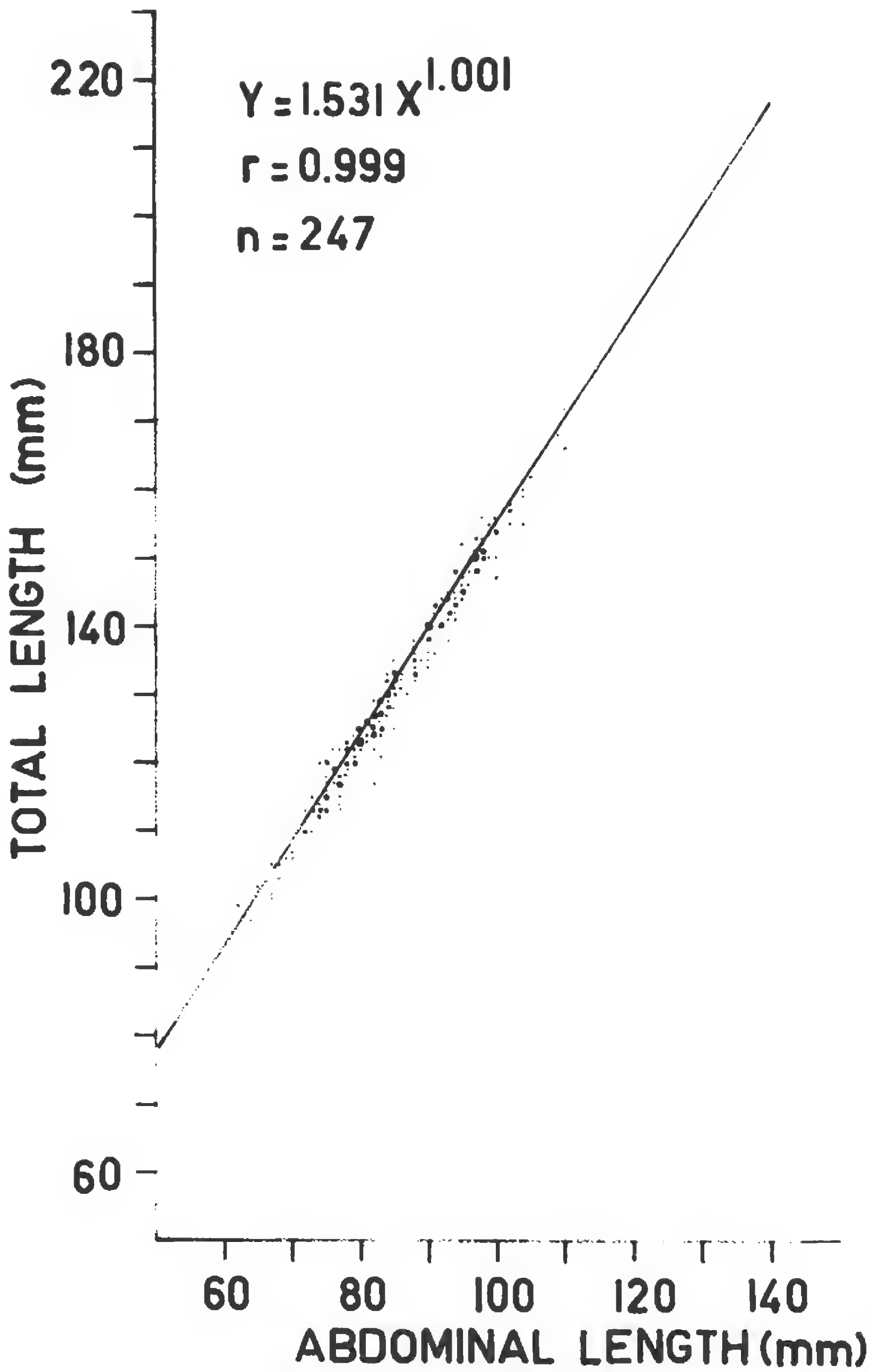

Figure 3. Regression analysis of total length-abdominal length in females of brown shrimp.

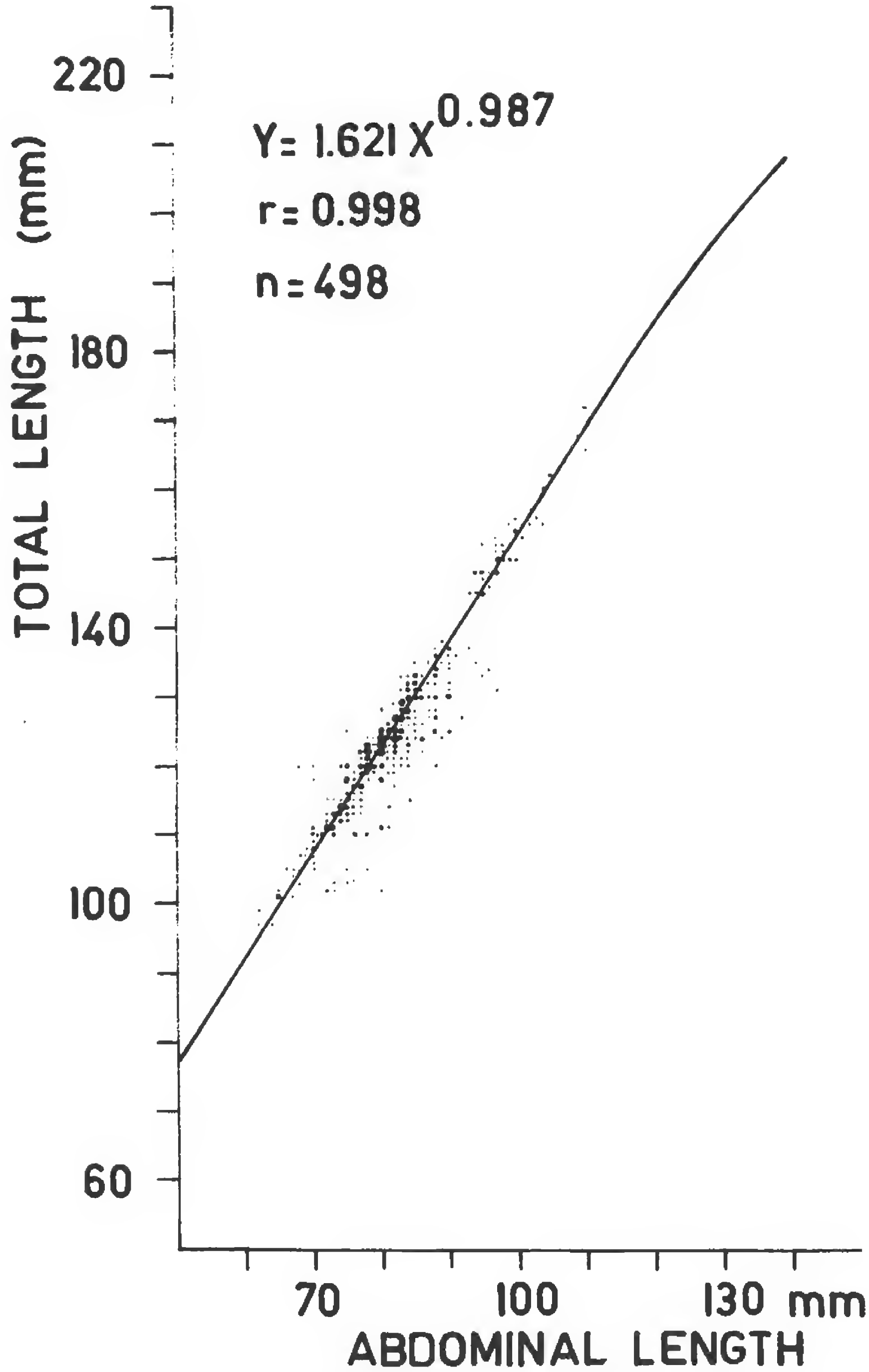

Figure 4. Regression analysis of total length-abdominal length of brown shrimp (both sexes combined).

gotten for each sex are slightly different, but the calculated constants of the complete samples are intermediate, as follows:

$$\begin{aligned} \text{Males: } W &= 0.000214\ 1^{2.325} & r &= 0.968 \\ \text{Females: } W &= 0.000010\ 1^{2.973} & r &= 0.997 \\ \text{Both sexes: } W &= 0.000023\ 1^{2.799} & r &= 0.986 \end{aligned}$$

It is pertinent to point out that in the first case (Fig. 5), the value of the exponent seems to be underestimated. According to data published by Chin (1960), values above three are expected. The exponent for female length (Fig. 6), and the one of both sexes together (Fig. 7), are closer to those expected. Growth is supposed to be isometric (at least in this group of crustaceans), and for this reason, the theoretical expected value for that parameter is three.

One of the reasons the formerly obtained result is not satisfactory is the narrow range of sizes of the male shrimp sampled for biometric study (in spite of which, the total length-tail length ratio found in this sex seems to be quite admissible). From the data obtained, their narrow size range limited the range of conclusions, and consequently the necessity of getting more sample increases, since at present the probabilities of erroneous results are very large, due also in part to the limited accuracy of measurement equipment. Also, Cook and Lindner (1970) point out that old shrimp are proportionally heavier than young. Nevertheless, the correlation coefficient was quite high in all cases, particularly in females.

Growth. For growth studies, the 22 continuous monthly samplings were used. The samples were taken in a cannery at Tampico. The monthly data were grouped in 3-mm size classes and represented by the Petersen method, that is by length–frequency curves. The cumulative frequencies of each month were plotted on probability paper in the same way as the example in Fig. 1. With this graphic method it was possible to determine how many age classes were present in each monthly sample, and at the same time to show some anomalies in these data, because it was evident that in some months there were more age classes than in others. Those anomalies are attributable, apparently, to involuntary sampling errors, which were not completely random. Nevertheless, they were very useful for inferences about growth of individuals in the population.

The mean values of monthly age classes found were grouped in a partially subjective way, for this was the only way possible to eliminate some of the sources of error included, since the sampling time, the intrinsic variations of population, and those due to ecological factors, such as temperature, that modify not only growth rate, but the velocity of physiological processes in general and their effects are also reflected among others in the growth.

The selection of age classes by this method has the convenience

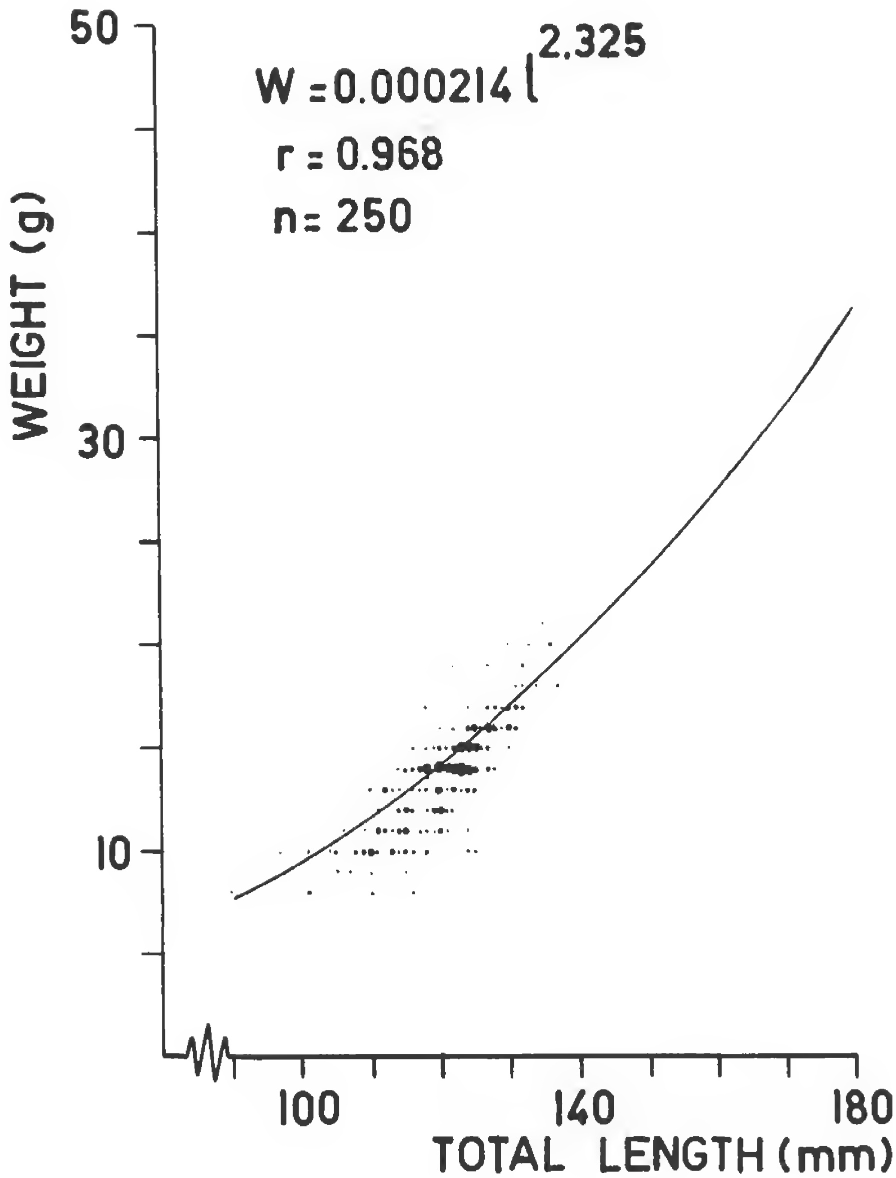

Figure 5. Regression analysis of length-weight in males of brown shrimp.

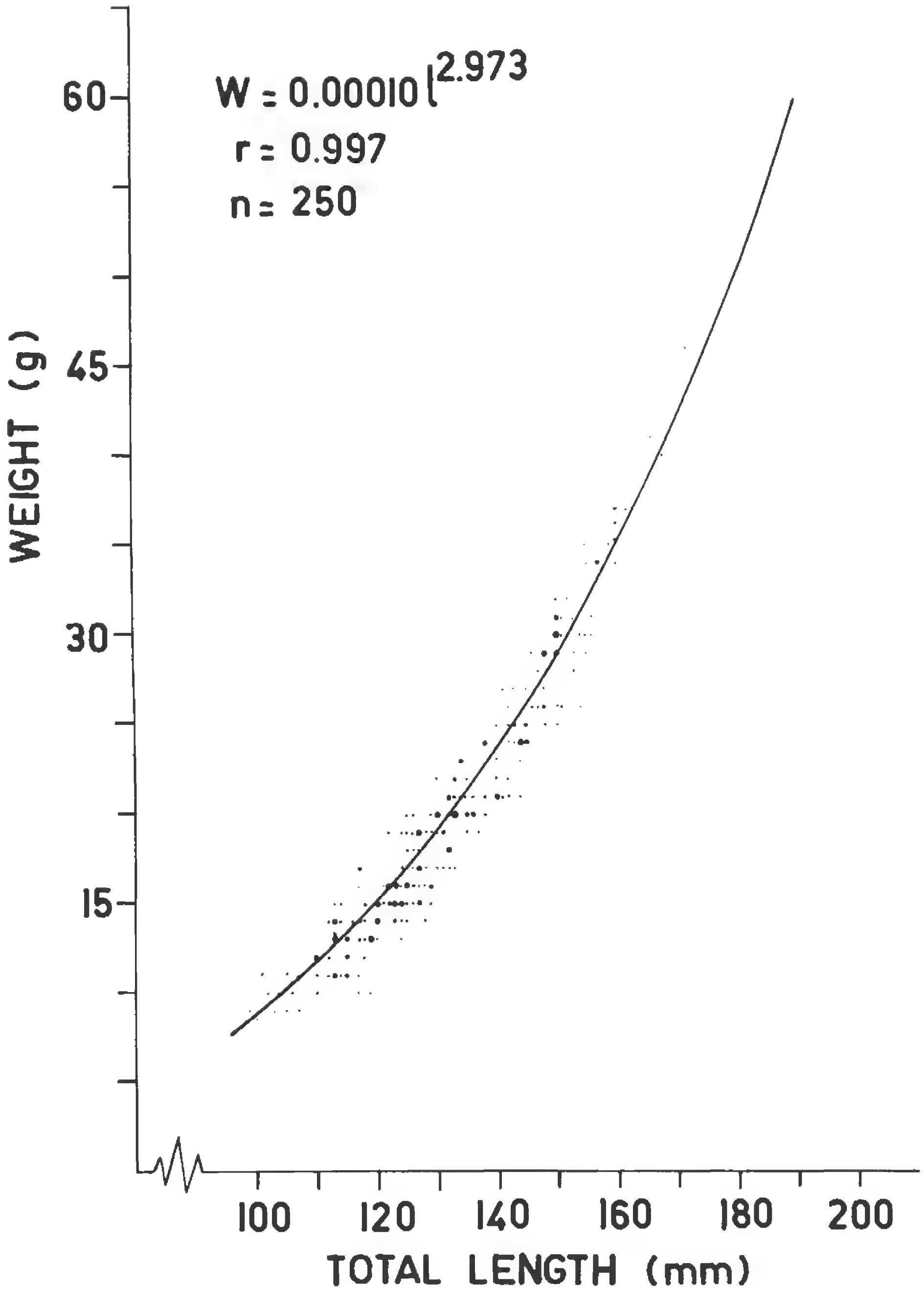

Figure 6. Regression analysis of length-weight in females of brown shrimp.

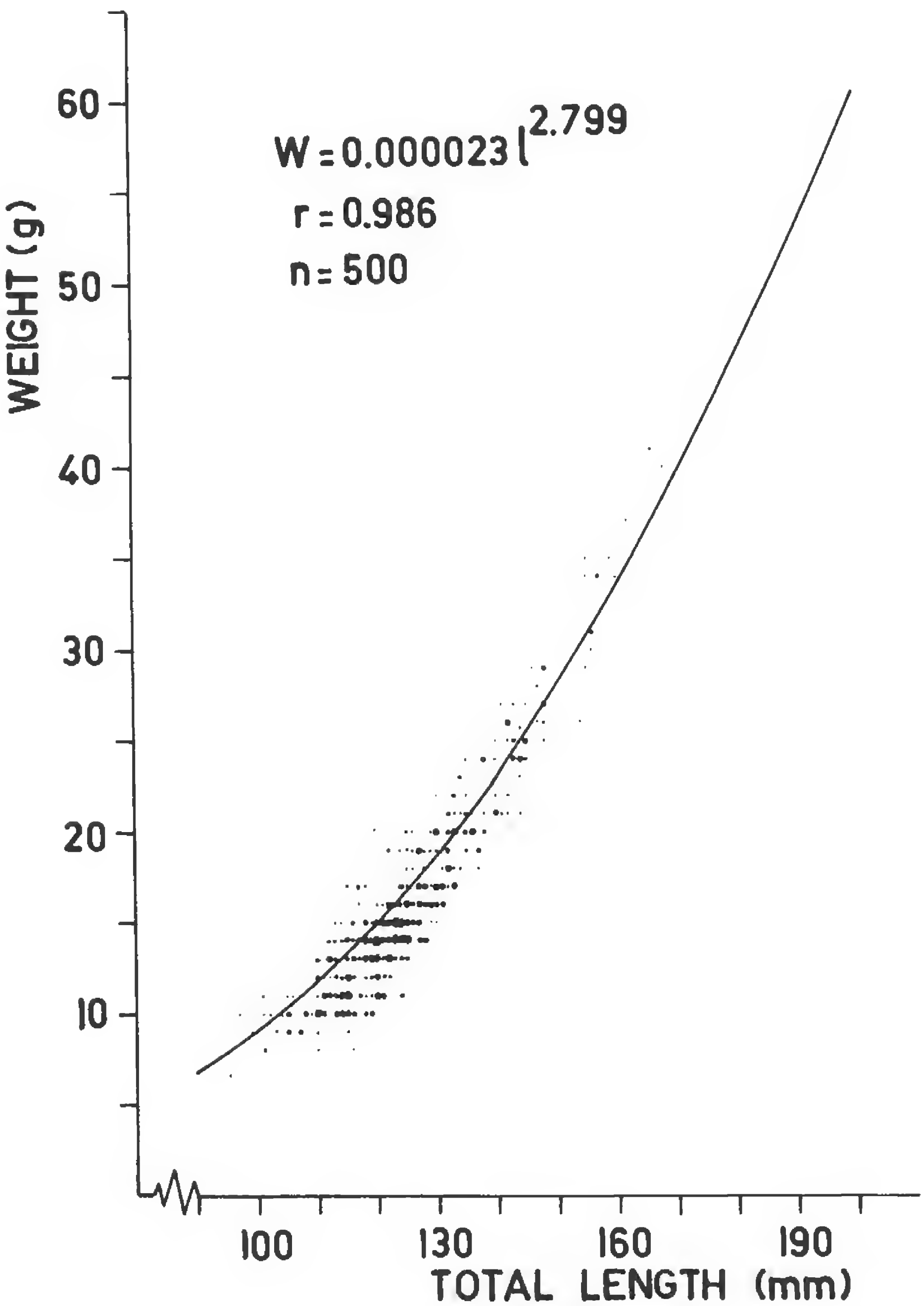

Figure 7. Regression analysis of length-weight of brown shrimp (both sexes combined).

of reducing the variations in growth caused by the presence of intermediate age classes, by seasonal changes and by other ecological factors, from which a series of size classes result whose values represent the average growth rate of the analyzed population. For this reason in Fig. 8 by following the monthly growth of each age class, identified by letters, if some discrepancies are noticed, it is because it was necessary to make some adjustments to minimize extreme variations.

The mean values of selected age classes are indicated in Table 1. With respective averages obtained for each sex a Ford–Walford plot was done (Fig. 9), graphic method to estimate the average maximum length of individuals in the population studied, finding $L\infty = 117$ and 150 mm of abdominal length for males and females. With all these data, those of age classes and $L\infty$, transformations were made to determine their corresponding values in total length; this was done by using the regression formulas previously calculated, and with them the von Bertalanffy growth equation was fitted, as follows:

$$l = L\infty\ [1 - e^{-k(t-t_o)}]$$

where:

l = Length at age t in mm
$L\infty$ = Average maximum length
k = Constant, proportional to catabolic rate
t = Age, in months in this case
t_o = Theoretical adjustment parameter, which expresses the age when the length is zero.

For additional details about this model, refer to Beverton and Holt (1957), Ricker (1958), Cushing (1968), Gulland (1969) and similar texts.

On following the curve as far as its origin, it was found to be reasonably well fitting in very small sizes, and it could be seen on the average, that the smallest age class fitted should be 4 months old, nine the elder in males, and ten in females.

The constants found in this case are shown in the following formulas, and the curves that they describe are also shown in Fig. 10.

$$\text{Males: } l = 178.1\ [1 - e^{-0.2567(t+0.2388)}]$$
$$\text{Females: } l = 236\ [1 - e^{-0.162(t+0.759)}]$$

With the growth model it is possible to express growth not only in terms of length but also in weight. This can be accomplished by transforming the values of $L\infty$ into its corresponding weight and raising the rest of the member to cube; the constants k and t_o do not modify. The result is a sigmoid curve whose inflection point is found at the third part of the value of asymptotic weight or $W\infty$ of that population. The transformation of length into weight was done with

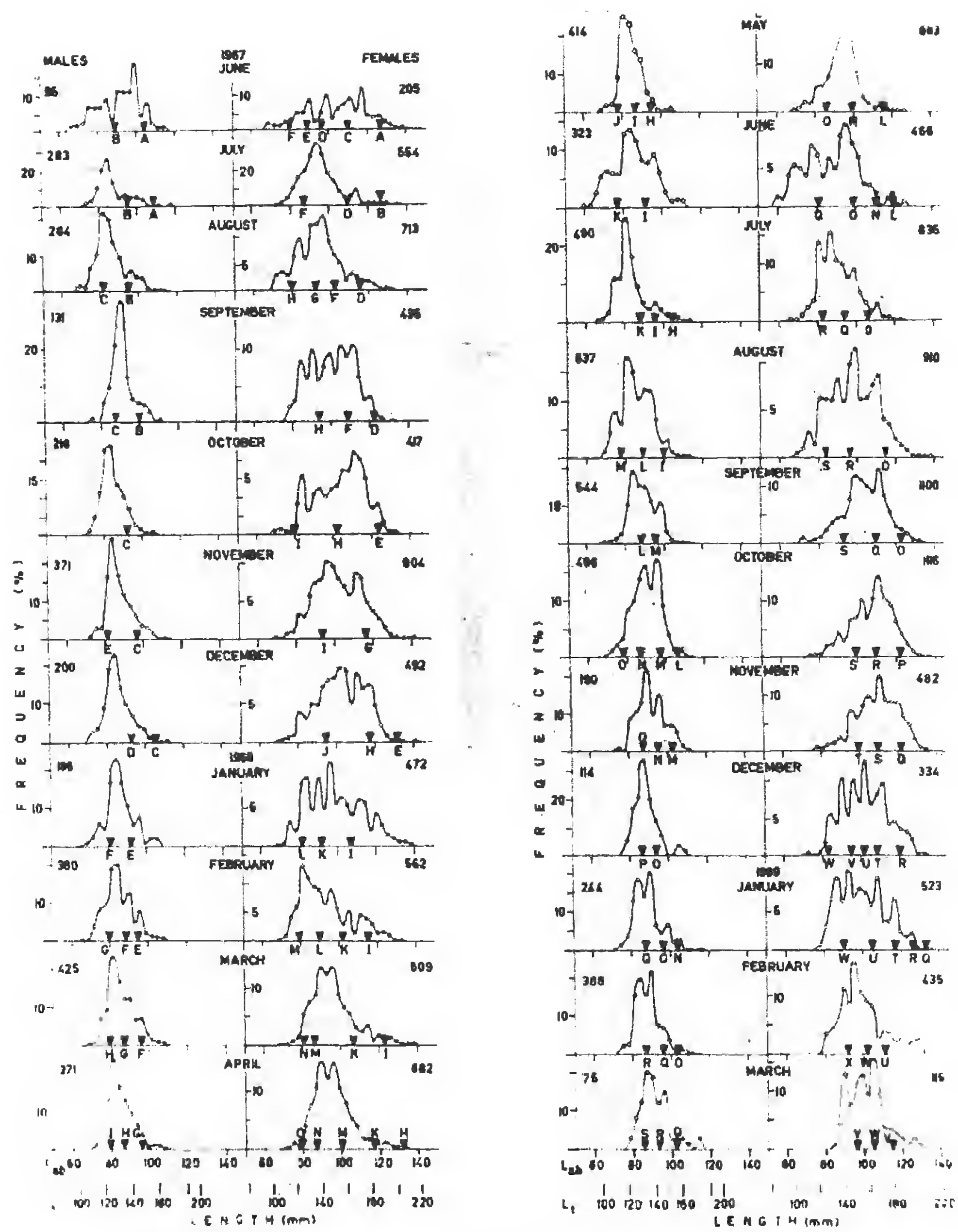

Figure 8. Monthly tail length-frequency curves of males and females of brown shrimp on which all the sampling period is represented. Mean length values of successive generations are identified by letters. The corresponding total length scale (L_t) is also shown below.

Table 1.

Monthly age classes determined from the analysis of frequencies made with probability paper. They are represented as abdominal length, in mm. Each generation is identified by letters. (These values are also shown in Figure 12)

Generation	Mean size values of monthly age classes					
	I	II	III	IV	V	VI
A					103.5	108.0
B		88.5	94.5	94.5	99.0	
C	82.0	87.0	91.5	96.0	105.0	
D			93.0			
E	81.0		91.5	94.5		
F	81.0	88.0	96.0			
G	79.0	87.0	96.0			
H	79.0	87.0	94.5		105.0	
I	79.0	87.0	91.5	96.0	100.0	
J	78.0					
K	77.0	88.0				
L		89.5	95.5	106.5		
M	78.0	88.5	97.5	102.0		
N		87.0	94.5		103.5	
O	78.0	87.0	93.0	96.0	103.5	
P		85.5				
Q		87.0	96.0	102.0		
R		87.0	93.0			
S		85.0				
Average	79.2	87.3	94.1	98.4	102.8	108.0

the regressions previously determined. But in the case of males and with the considerations formerly made, it seemed pertinent to take the results of males and females computed together instead of those of males only in order to reduce the risk of working with wrong data, mainly when there is the antecedent of no marked differences between the sexes (Chin 1960). Therefore, the results of growth in weight are shown in the following expressions:

$$\text{Males: } w = 46 \quad [1 - e^{-0.2567(t+0.2388)}]^3$$
$$\text{Females: } w = 113 \quad [1 - e^{-0.162(t+0.759)}]^3$$

The expressions seem to be similar to those of the length growth.

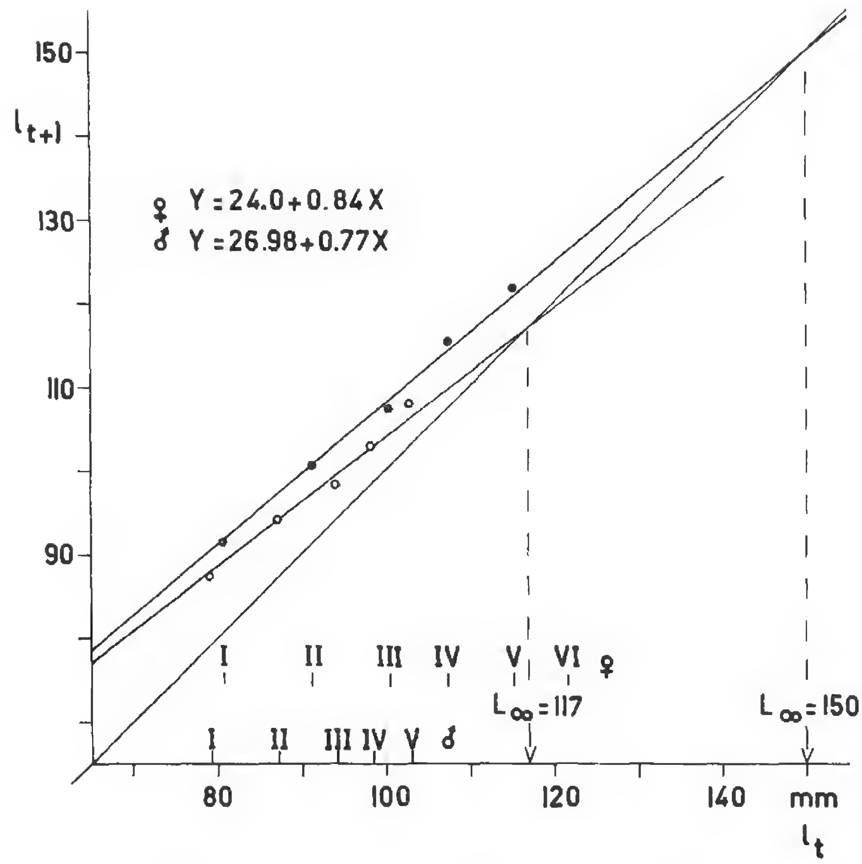

Figure 9. Ford-Walford graph of abdominal length in mm at age t against length at age t+1 for males and females of brown shrimp.

Nevertheless, the differences existing between L∞ of each sex are equivalent to quite distinct weights of specimens of the same age but different sex, variations that increase with age. This can be seen in Fig. 11 where the growth in weight is represented by sex.

The sizes and weights of each monthly age class calculated by means of the von Bertalanffy growth model are shown in Table 2, whose variations explain well the differences in growth found by Williams (1955), Loesch (1965), and St. Amant et al. and Joyce (both after Cook and Lindner 1970) upon juvenile brown shrimp populations, somewhat larger growth rates than those found during the present analysis for similar size ranges.

Finally, bearing in mind that only global data are frequently available, for example, the Gulf Coast Shrimp Data, in which it is not

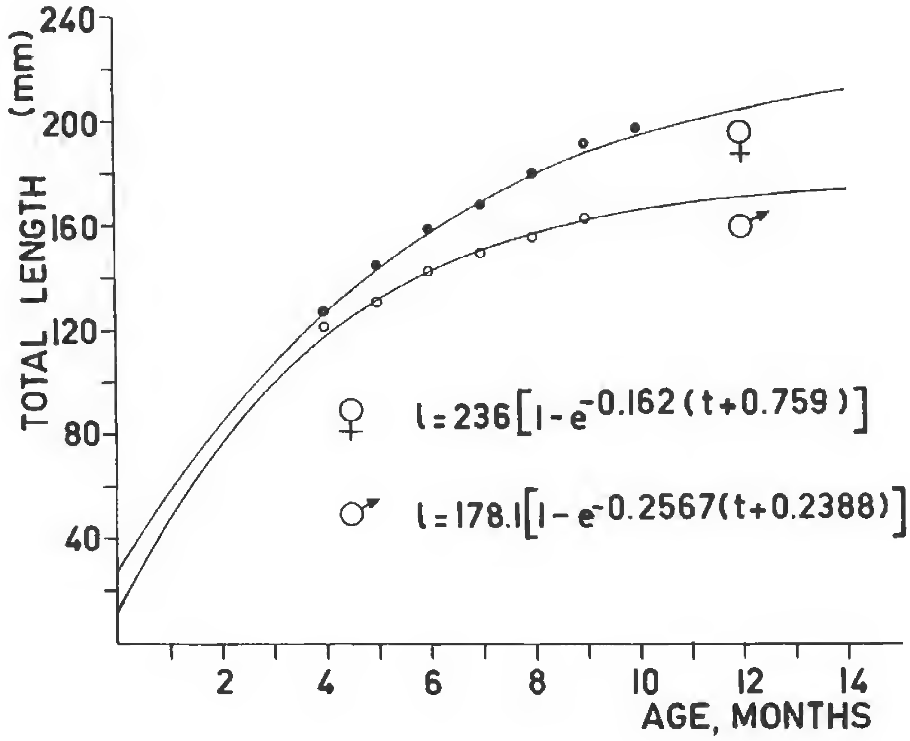

Figure 10. Von Bertalanffy growth curves, in length, found for each sex of brown shrimp. Observed values of age classes are shown by small circles.

possible to separate the differences due to sex, it was decided to calculate growth parameters of the population as a whole, which was done in the following way: with the values of L_∞ and W_∞ determined for each sex, new average values were obtained and were considered as L_∞ and W_∞ of the population, and the age classes were those determined by making an average of the resulting pairs of values formerly analyzed after the growth rate was considered for each sex separately. Therefore, the latest obtained results are as follows:

$$L_\infty = 207 \text{ mm} \quad W_\infty = 70 \text{ g}$$
$$k = 0.1904 \quad t_0 = -0.872$$

The graphic representation of individual growth rate of the *Penaeus aztecus aztecus* population studied is shown in Fig. 12, and in Table 3 the length and weight values for each month of age are also indicated.

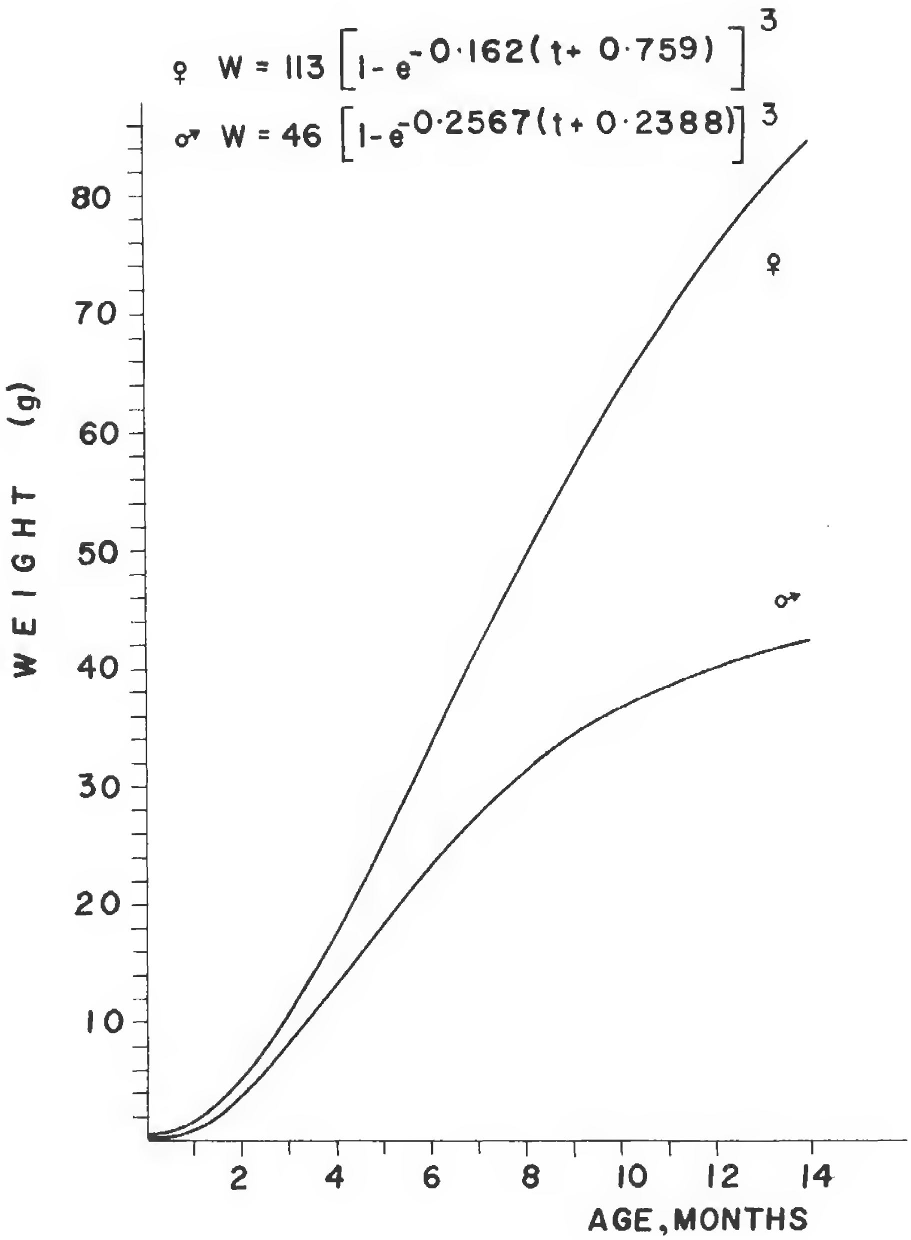

Figure 11. Von Bertalanffy growth curves, in weight, for each sex of brown shrimp.

Table 2.

Growth rate in length and weight of *Penaeus aztecus aztecus* Ives calculated for each sex and month during the first fourteen months of age

Age (Months)	Length (mm)	Increase (mm)	Weight (g)	Increase (g)
MALES				
1	48.5	37.9	0.9	0.9
2	75.7	27.2	3.7	2.8
3	100.6	24.9	8.3	4.6
4	118.3	17.7	13.4	5.1
5	131.8	13.5	18.6	5.2
6	142.0	10.2	23.4	4.8
7	150.4	8.4	27.7	4.3
8	156.6	6.2	31.3	3.6
9	161.4	4.8	34.3	3.0
10	165.3	3.9	36.7	2.4
11	168.2	2.9	38.7	2.0
12	170.4	2.2	40.3	1.6
13	172.1	1.7	41.5	1.2
14	173.5	1.4	42.5	1.0
FEMALES				
1	58.3	30.9	1.7	1.5
2	85.0	26.7	5.3	3.6
3	107.6	22.6	10.7	5.4
4	127.0	19.4	17.5	6.8
5	143.3	16.3	25.2	7.7
6	157.1	13.8	33.3	8.1
7	169.0	11.9	41.4	8.1
8	179.0	10.0	49.2	7.8
9	188.0	9.0	56.6	7.4
10	195.0	7.0	63.4	6.8
11	200.9	5.9	69.7	6.3
12	205.0	4.1	75.3	5.6
13	210.6	5.6	80.3	5.0
14	214.4	3.8	84.7	4.4

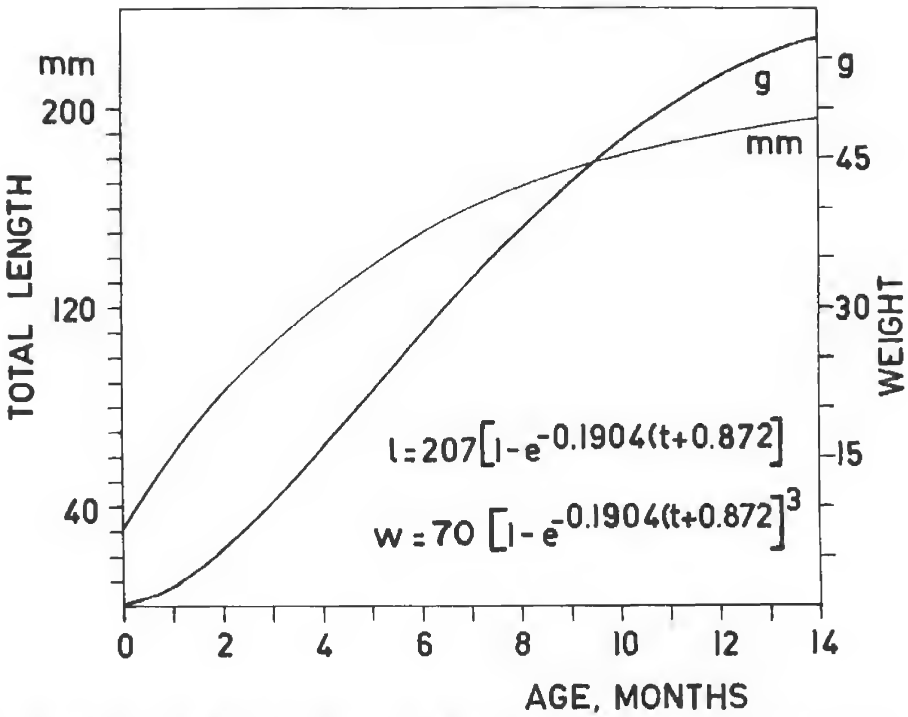

Figure 12. Von Bertalanffy growth curves found for all brown shrimp population sampled (both sexes combined). The curves show the longitudinal and ponderal average growth of individuals.

DISCUSSION OF RESULTS AND CONCLUSIONS

As a corollary of biometric study of the analyzed population, it is concluded that the total length–abdominal length ratio shows a mostly straight relationship in both sexes, and that the observed differences in each sex are very slight. For this reason, it is supposed that the calculated population formula is representative of such a transformation, a characteristic that on the other hand means that the shrimp growth is isometric respectively to these two factors. The calculated relationship was made on a basis of the need of knowing the total length of specimens formerly sampled, and it was necessary to make a reference calculated in terms of total lengths of the shrimp.

Concerning the length–weight relationship, it is pertinent to point out that the exponent of length usually is a value which fluctuates about three, and in this case described an isometric growth, characterized from Ricker (1958), because the specific gravity and the body form remain constant, regardless of the size of the organism. Former experiences with shrimp (Hall 1962, Butler 1970, Chin 1960,

Table 3.

Monthly growth rate in length and weight of brown shrimp calculated for all population samples (both sexes combined)

Age (Months)	Length (mm)	Increase (mm)	Weight (g)	Increase (g)
1	61.8	30.1	1.9	1.7
2	87.0	25.2	5.3	3.4
3	105.5	18.5	9.9	4.6
4	121.1	15.6	15.5	5.6
5	139.6	18.5	21.3	5.8
6	151.1	11.5	27.2	5.9
7	160.8	9.7	32.8	5.6
8	168.5	7.7	37.9	5.1
9	175.2	6.7	42.6	4.7
10	181.0	5.8	46.7	4.1
11	185.4	4.4	50.3	3.6
12	189.1	3.7	53.4	3.1
13	192.2	3.1	56.1	2.7
14	195.0	2.8	58.3	2.2

Kutkuhn 1966, George 1970a and 1970b, Nikolic' and Garcia 1970, Cruz-Morejon and Cadima 1970, Angelescu and Boschi 1959, and Chávez and Rodríguez-de la Cruz (1971), suggest that at least in this group, the growth shows a remarkable tendency to isometry, where the calculated exponents fluctuate around three, ranging from 2.55 to 3.25. These variations are probably due to insufficient data, small number of samples, to variations in condition coefficient of shrimp, or to the influence of other physiologically responsible factors.

Gulland (1969) points out that there is a wide number of growth equations, but none is entirely satisfying in all possible situations. Dickie (from Tesch 1968), asserts that growth curves are valuable for descriptive purposes, but the biological interpretation of models and their parameters still present great difficulties. The von Bertalanffy growth model in the author's opinion, has been shown to be quite satisfactory; besides, it should be kept in mind that this model is the best known and the most widely used in production studies on species of economic value; it satisfies reasonably the two most important criteria: it fits most of the observed data on growth, and can be readily incorporated into stock assessment models.

The growth analysis developed in the present paper seems to offer

a good outlook for further application to the penaeid shrimp group. This group presents serious difficulties for the determination of age and growth of the species belonging to it, because of its variability due to environmental changes. There is also the impossibility of referring the age classes to growing marks to check the analytical inferences made from the information acquired with the samples.

With the comparative study of size–frequency curves, it is possible to figure out that in analyzed samples there is a small percentage of shrimp whose age ranges are from 2 to 13 months old in males, approximately, with lengths ranging from 93 to 172 mm in each case; in females, all seems to show that age classes ranging from 2 to 15 months old are present (the number of extreme size classes is also small), whose lengths lie between 91 and 216 mm. It is supposed that the presence of larger shrimp is a random occurrence rather than the result of an ecological factor. These large sizes were found from June through August in both sexes, from January until March in males, and from November to March in females. The smaller shrimp, approximately 2 months old, were observed quite well chronologically located. In spite of the fact that Gulf of Mexico shrimps virtually reproduce the year-round, the presence of the smallest shrimp is necessarily interpreted as a maximum of reproduction existing at least 2 months before their recruitment. If recruitment of such tiny shrimp occurs mainly from June through August, it is supposed that they belong to a generation born from March through May (it is necessary to add 15 days to the apparent age, because of the larval stage duration). In part, this confirms the opinion of Kutkuhn (1962) about the increased spawning activity during March–April and September–October.

The results obtained by the use of probability paper to determine the size classes suggests more objectivity than the use of the size–frequency curves only (Chávez and Rodríguez-de la Cruz 1971), especially when the number of samples is small. For instance, either one of these methods may be profitable, but the accuracy of the results is determined by the experience of the analyst.

It is necessary to keep in mind that the present study was undertaken with the idea of determining the average individual growth rate, regardless of the seasonal variations, due to the fluctuating changes of ecological factors determining the habitat of *P. aztecus aztecus* populations. The study was made in that way because on incorporating growth parameters into stock assessment models, extreme variations capable of modifying the results are discarded.

SUMMARY

A study of brown shrimp (*Penaeus aztecus aztecus* Ives, 1891) was undertaken. The data were obtained from samplings made twice

or thrice a week in Tampico (Mexico) canneries, during the period from June 1967 to March 1969. The data consist of abdominal length records of 20,003 specimens of both sexes, 6,879 males and 13,124 females. An additional sampling of 500 specimens was made in July 1971 in which total length, tail length and weight were recorded. These data were analyzed as logarithmical regressions establishing the corresponding relationships, of which the formulas are as follows:

Total length (Y) — abdominal length (X) ratio:

Males:	$Y = 2.05\ X^{0.932}$	$r = 0.999$
Females:	$Y = 1.531\ X^{1.001}$	$r = 0.999$
Both sexes:	$Y = 1.621\ X^{0.987}$	$r = 0.998$

Weight (W) — length (l) ratio:

Males:	$W = 0.000214\ l^{2.825}$	$r = 0.968$
Females:	$W = 0.000010\ l^{2.973}$	$r = 0.997$
Both sexes:	$W = 0.000023\ l^{2.799}$	$r = 0.986$

Tail length data were grouped and represented as monthly length–frequency curves, to which mean values of age classes found in each month were incorporated. These values were obtained after analyzing each monthly group of data on probability paper. Once the mean values of age classes were obtained, a Ford–Walford plot was made and a von Bertalanffy growth curve was fitted. The constants are as follows:

Males:	$L\infty = 178.1$ mm	$W\infty = 46$ g
	$k = 0.2567$	$t_0 = -0.2388$
Females:	$L\infty = 236$ mm	$W\infty = 113$ g
	$k = 0.162$	$t_0 = -0.759$
Both sexes:	$L\infty = 207$ mm	$W\infty = 70$ g
	$k = 0.1904$	$t_0 = -0.872$

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Gulf Research Reports

Volume 4 | Issue 2

January 1973

Nutritional Components of the Standing Plankton Crop in Mississippi Sound

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DOI: 10.18785/grr.0402.13

NUTRITIONAL COMPONENTS OF THE STANDING PLANKTON CROP IN MISSISSIPPI SOUND[1]

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ABSTRACT

A study on seasonal changes in the nutritional components of standing plankton biomass was made from 20 April 1965 to 6 September 1966. Plankton were separated into net plankton and nannoplankton fractions. Nannoplankton[3] standing biomass exceeded by 72 times that of net plankton.

Although protein and carbohydrate levels were higher in net plankton on a unit weight basis, total nutrients available from nannoplankton were substantially higher. Some seasonal trends were apparent as changes in the standing biomass in net plankton. Nannoplankton exhibited no seasonal trends. Lipid and caloric values of net plankton showed seasonal trends similar to those shown by dry weight.

INTRODUCTION

Early studies on marine plankton were directed primarily toward species composition, geographical distribution and seasonal successions. The importance of plankton to fisheries led to studies of plankton biomass, with considerable recent emphasis on plankton production as indicated by primary photosynthetic productivity. There are relatively few data, however, on specific nutritional components—carbohydrate, protein, and lipid—available from plankton and on quantitative seasonal changes in these components. Furthermore, although nannoplankton comprises the major fraction of the total plankton and exceeds the net plankton manyfold (Banse 1964, Pomeroy and Johannes 1966), those nutritional component data available relate only to net plankton.

[1] This work was supported in part by National Science Foundation Grant No. BG–3452, and is extracted from a Ph.D. Thesis submitted to Department of Zoology, Mississippi State University.

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[3] It should be noted that the authors did not separate the nannoplankton from what has been called the nannodetritus and both components are included in the word nannoplankton, as used in this paper. Ed.

Mississippi Sound is regarded as a highly productive body of water (Gunter 1962, 1963, Christmas, Gunter, and Musgrave 1966) because of the influence of nutrient rich waters from Mississippi River (Riley 1937). This report is concerned with measurements of net plankton and nannoplankton dry weight, protein, and carbohydrate, and with lipid and caloric content of net plankton during a yearly cycle in Mississippi Sound.

MATERIALS AND METHODS

From April 20, 1965 to September 6, 1966, plankton was collected as near monthly as logistics and weather permitted from 6 sampling stations along two transects across Mississippi Sound—from Marsh Point to Horn Island (Fig. 1) and from Ship Island to Biloxi Beach (Fig. 1). The order of running the transects was systematically reversed from cruise to cruise to avoid sampling bias, but on each cruise one transect was worked by day and the other by night.

Composite net plankton samples were taken by pumping water from surface, mid-depth, and near bottom into a No. 20 plankton net

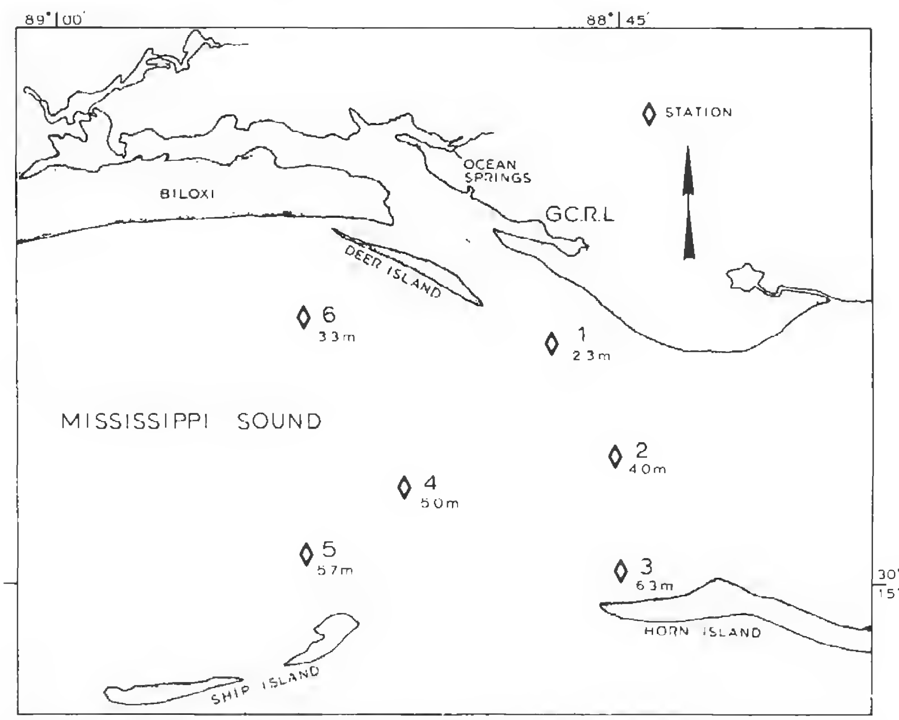

Figure 1. Map of Mississippi Sound showing sampling stations and depths. GCRL represents the site of the Gulf Coast Research Laboratory.

(76 μ mesh size) submerged in a water-filled container. The water was pumped at the rate of 190–240 liters/min. for 30 min. with a pre-calibrated pump. Leong (1967) has discussed plankton sampling by pumping in oceanographic situations. Our conditions were less severe because we used 5 cm pump instead of 1.27 pump and pumped water from a maximum depth of 8 meters rather than from 120 meters. As a result there should be less churning effect and less fragmentation of the planktonic organisms. A 19–liter aliquot of net filtrate was taken at each station as a nannoplankton sample. Both this aliquot and the net plankton sample were kept chilled by ice until return to the laboratory.

The nannoplankton samples were flocculated with potassium alum ($KAl(SO_4)_2$) to precipitate all suspended matter, plankton centrifuges having proved unsatisfactory for this purpose. The flocs were dissolved with just sufficient 3N hydrochloric acid and centrifuged at 1500 RPM for 15 minutes. Both net and nannoplankton concentrates were freed from water and salt by filtration on 0.8 μ Millipore type AA filters with a rapid wash with isotonic ammonium formate (Parsons, Stephens and Strickland 1961). Humphrey and Wootton (1966) have shown by pigment studies with *Gymnodinium, Nannochloris*, and sea water samples that delicate, small phytoplankton are retained as well by this Millipore filter as by those of lesser pore size. Samples were dried to constant weight at 105° C (Curl 1962) against a Millipore filter blank, scraped from the filter, and homogenized by grinding.

For measurement of protein content, portions of plankton homogenates, and albumin, used as standard, were hydrolyzed in a sealed vial with 6N HCl for 12 hours at 120° C (Welcher 1963). Hydrolysates were filtered, dried on a steam bath, and diluted to a standard volume. Amino acid content of plankton fractions and albumin hydrolysates was determined colorimetrically as leucine equivalents using a modification of the ninhydrin technique of Landua and Awapara (1949). The albumin equivalent of leucine, determined experimentally, was 6.97 μmol leucine/mg albumin.

Plankton carbohydrates were determined by hydrolyzing portions of homogenates, and oyster glycogen, used as standard, with 3N HCl for 1½ hours at 95° C. Hydrolysates were dried and glucose content was determined colorimetrically by the method of Folin and Wu (Department of the Army 1951).

Nannoplankton samples were too small for routine lipid analysis. Lipid from net plankton was extracted with chloroform–methanol–water (2:2:1) in a screw-capped Waring blender jar (Bligh and Dyer 1959). The homogenates were filtered and allowed to stand in separatory funnels with Teflon stopcocks until phases separated. The chloroform layer was removed, washed with chloroform–methanol–water

(3:48:47) (Folch, Lees and Stanley 1957), and dried with infrared lamp. Total lipid in the aliquots was determined spectrophotometrically by the method of Snyder and Stephens (1959) using triolein as standard.

Caloric measurements on net plankton were made according to Parr Manual No. 122 (1951) in a Parr Peroxide Bomb Calorimeter, Model 1401. Dried net plankton samples were ground to pass a 60 mesh screen. Particle size is important, because combustion reactions occur in a few seconds and large particles, if present, may not burn completely. Benzoic acid was used as combustion aid.

Ash content of plankton samples was determined by hot nitric acid digestion of the dried homogenate followed by ignition to constant weight in a muffle furnace at 550° C.

Salinity and temperature were determined *in situ* at each station by means of a Beckman Induction Salinometer. Figure 2 shows mean surface water temperatures during the course of this study.

All data for biomass, nutrients, and caloric values have been computed for a water column of 1 sq m area.

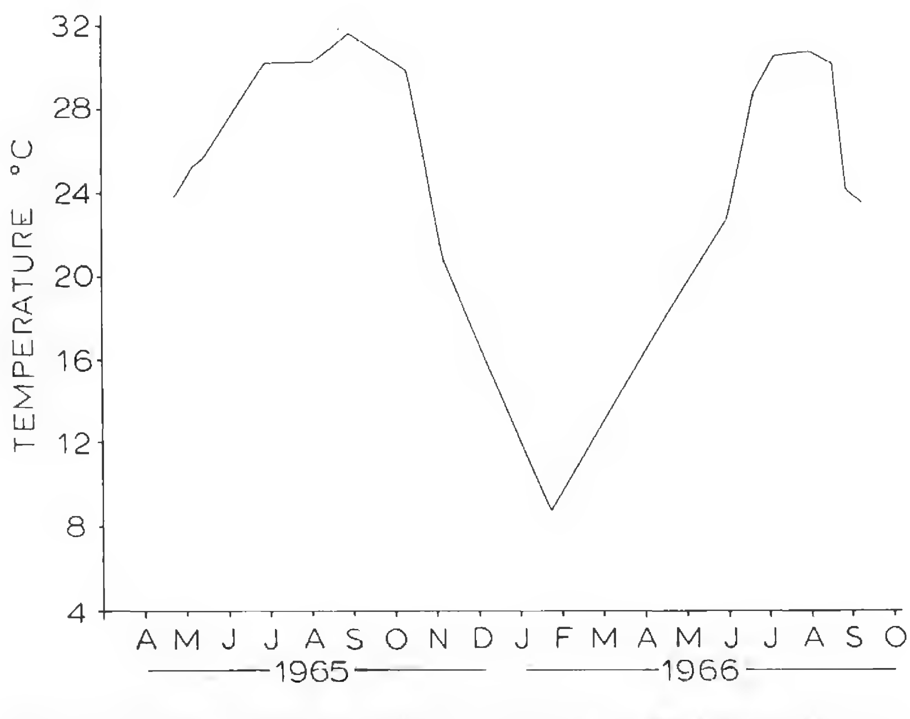

Figure 2. Mean surface temperature at six sampling stations from 20 April 1965 to 6 September 1966.

RESULTS

Dry Weight: The net plankton dry weight values of 637 mg/sq m and 452 mg/sq m (Fig. 3, Table 1) observed in April and May 1965,

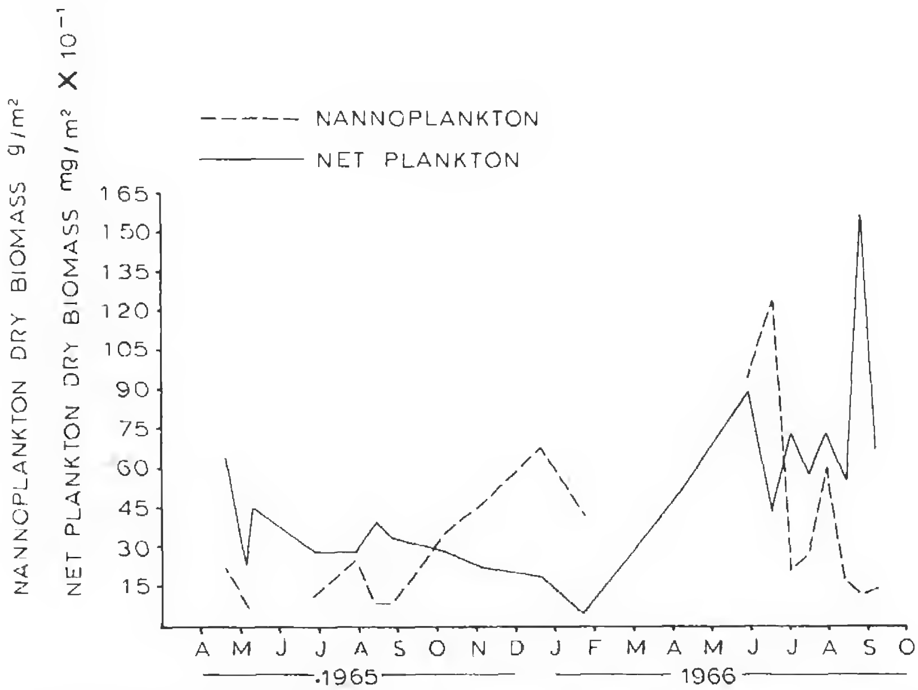

Figure 3. Seasonal variation in mean values of dry biomass of net plankton and nannoplankton.

respectively, derived from a plankton increase because of vernal warming in Mississippi Sound (Thomas and Simmons 1960). The peak of 401 mg/sq m in August 1965, appeared to be due to increased herbivore populations. The magnitude of spring and summer peaks in 1966 was considerably higher than peaks in 1965. Deevey (1960) indicated that the zooplankton seasonal cycle in nearshore waters may be extremely variable from one year to the next. On several occasions in summer 1966 concentrations of a blue-green alga, *Trichodesmium* sp., were observed in surface waters. The algal abundance would contribute markedly to the upswing in standing biomass. Beginning in late summer 1965, a gradual decrease in standing dry weight ensued, with a minimum of 43 mg/sq m in January 1966. A similar trend was noted again in 1966, when average values showed a sharp decline during September, decreasing from 1560 mg/sq m to 681 mg/sq m (Table 1).

Table 1.

Summary of Mean Values for Dry Weight, Nutrients, Ash Content and Caloric Values in the Standing Biomass of Net Plankton. Means have been Computed from Results at Six Stations

Date	Dry Weight mg/sq m	Protein mg/sq m albumin	Carbohydrate mg/sq m glycogen	Lipid mg/sq m triolein	Ash mg/sq m	Total nutrient and ash as percent dry weight	kcal/ sq m
1965							
20 April	637	158	29	15	217	65	1.7
4 May	228	62	9	8	113	84	0.5
11 May	452	100	7	15	230	78	0.9
25 June	284	96	9	11	147	92	0.6
31 July	282	63	6	8	171	88	1.1
14 August	401	104	7	11	208	82	0.8
26 August	337	66	6	16	130	65	1.1
7 October	285	73	4	4	166	87	0.6
4 November	225	47	4	5	129	82	0.5
20 December	194	17	10	1	110	71	
1966							
23 January	43	15	1	1	22	90	
8 April	508	92	24	9	175	59	1.3
28 May	898	172	15	11	463	74	2.2
17 June	444	76	7	16	219	72	1.0
1 July	739	217	37	12	389	88	1.9
15 July	581	197	34	16	276	90	1.1
19 July	740	271	20	19	402	96	1.8
13 August	566	185	32	14	292	92	1.2
26 August	1560	470	32	48	778	85	3.3
6 September	681	235	16	34	310	87	1.7
Grand Mean	504	136	15	14	247	81	1.3

The nannoplankton dry weight exceeded the net plankton dry weight manyfold, and showed a mean ratio to net plankton of 140:1, with the maximum in winter and the minimum in summer (Tables 1, 2 and 3). Yentsch and Ryther (1959), on the basis of chlorophyll *a* values, and Johannes (1964), on the basis of dry biomass, pointed out that nannoplankton comprised the major fraction of the total plankton.

The nannoplankton crop showed no definite seasonal trend, biomass peaks at various stations appearing in spring, fall, midsummer, and midwinter (Fig. 3). Mean dry weight values ranged from 7.50 g/sq m to 21.8 g/sq m in spring and from 7.9 g/sq m to 25.4 g/sq m

Table 2.

Summary of Mean Values for Dry Weight and Nutrients in Nannoplankton. Means have been Computed from Results at Six Stations

Date	Dry Weight g/sq m	Protein g/sq m albumin	Carbohydrates g/sq m glycogen
1965			
20 April	21.8	1.4	0.5
4 May	7.5	0.8	0.1
25 June	10.9	1.3	0.5
31 July	25.4	1.8	0.6
14 August	8.0	0.9	0.3
26 August	7.9	0.5	0.3
7 October	37.0	1.6	1.1
4 November	46.7	1.3	1.4
20 December	67.6	1.1	0.5
1966			
23 January	42.8	1.0	2.3
28 May	95.2	2.7	0.5
17 June	123.5	6.3	6.0
1 July	22.8	2.3	1.4
15 July	28.5	1.7	1.0
29 July	61.2	3.5	1.3
13 August	17.2	3.2	0.7
26 August	12.4	2.5	0.4
6 September	14.8	2.9	0.6
Grand Mean	36.2	2.0	1.9

Table 3.

Seasonal Variation in Nannoplankton-to-Net Plankton Ratios for Dry Weight, Proteins, and Carbohydrates

Date	Dry Weight nanno/net	Proteins nanno/net	Carbohydrate nanno/net
1965			
20 April	34	9	17
4 May	33	13	17
25 June	38	13	62
31 July	90	29	100
14 August	20	9	48
26 August	24	7	57
7 October	130	22	278
4 November	208	27	310
20 December	348	64	55
1966			
23 January	996	65	2086
28 May	106	16	34
17 June	278	82	903
1 July	31	11	39
15 July	49	9	87
29 July	83	13	65
13 August	30	17	22
26 August	8	5	14
6 September	22	12	37

in summer 1965 (Table 3). An average nannoplankton rise was noticed starting in fall and reaching a maximum, 67.6 g/sq m, in December 1965. The nannoplankton–to–net plankton dry weight ratio was 996:1 in January 1966 and 8:1 in late August 1966, the highest and lowest for the entire study period (Table 3). Such an extreme difference in ratio probably resulted from low production of net plankton and little or no spawning and breeding activity of herbivores at a time when production at the nannoplankton level was high. Both fractions maintained higher average standing dry weights in summer than in winter, with a differential, larger increase in net plankton.

Protein: Protein comprised the largest component of net plankton nutrients. The dry weight–to–protein ratio was 3.7:1, equivalent to 27% protein. Parsons, Stephens and Strickland (1961), Raymont

(1963), and Blazka (1966) have shown considerably higher relative protein levels in net plankton, apparently because their samples were not contaminated by the large amounts of detritus, clay, and silt usually present in collections from Mississippi Sound. The high ash content in our net plankton samples should account for the low relative protein level.

Mean net plankton protein for all samples was 136 mg/sq m. The level varied from 62 mg/sq m to 158 mg/sq m between April and August 1965 (Fig. 4). With the seasonal temperature decline, protein

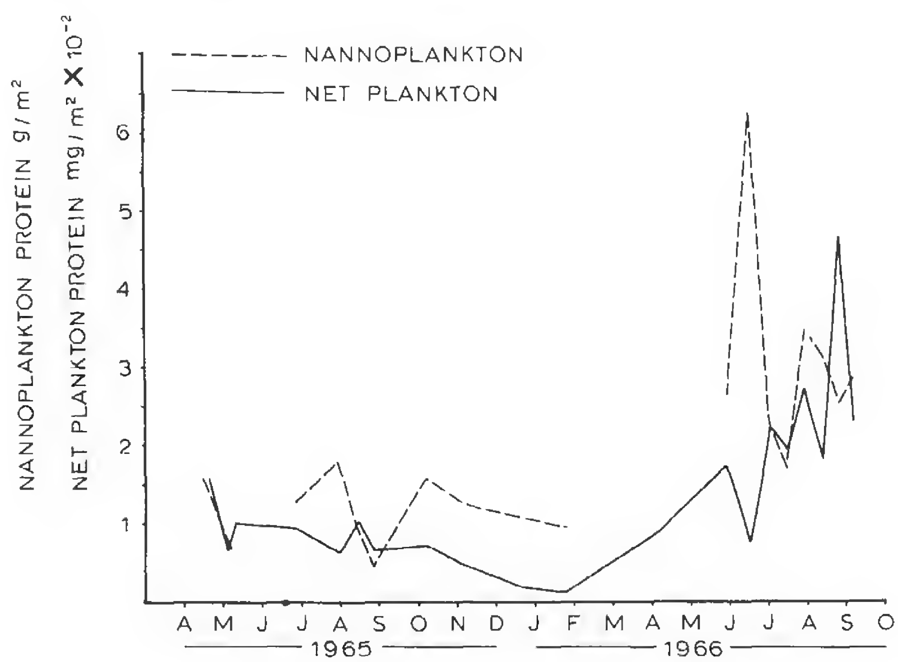

Figure 4. Seasonal variation in mean values of protein of net plankton and nannoplankton.

values decreased to 15 mg/sq m in January 1966. As temperatures rose again with the onset of spring, net plankton protein values again increased, reaching 470 mg/sq m in August 1966. The summer maximum for 1966 was considerably higher than the summer values for 1965 and followed the same trend as net plankton dry weight.

The dry weight-to-protein ratio in nannoplankton was 18:1, equivalent to 5.5% protein. Similar low levels of protein in smaller plankton organisms have been reported by Blazka (1966), Raymont (1963), and Parsons, Stephens and Strickland (1961). This supports the concept that nannoplankton are mainly composed of photosyn-

thesising elements and, hence, are mainly carbohydrate, not protein (Fig. 5). Nannoplankton protein ranged from 0.5 g/sq m to 1.8 g/sq m during the April–December 1965 period, with maximum and minimum occurring in the summer (Table 2). Data for 1966 indicated greater variability in available protein. Values fluctuated between 1.0 g/sq m and 6.3 g/sq m, with marked variations during the summer. Although the protein level in nannoplankton was extremely low, the nannoplankton–to–net plankton mean protein ratio on a water column basis was 24:1 (Table 3).

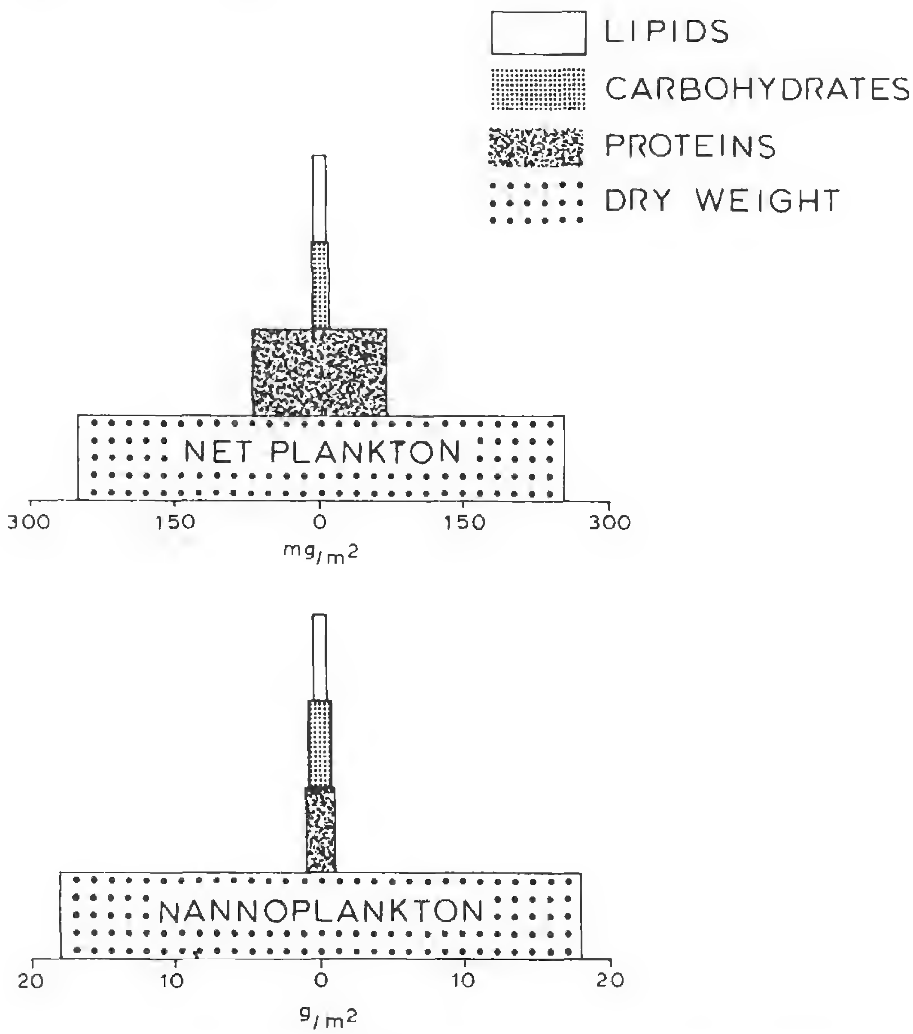

Figure 5. Average nutrient composition and dry weight of Mississippi Sound plankton.

Carbohydrate: Carbohydrate composed 3% of the dry net plankton sample, giving a carbohydrate–to–protein ratio of 1:9. Various biochemical studies on plankton agree that carbohydrate level in net plankton is relatively low and protein makes up most of the nutrient component (Raymont and Conover 1961, Parsons, Stephens and Strickland 1961, Blazka 1966). Carbohydrate values for April 1965 and April 1966 were 29 mg/sq m and 24 mg/sq m, respectively (Table 1). From late spring to winter 1965, values remained at or below 10 mg/sq m with a minimum of 1 mg/sq m in January 1966 (Fig. 6).

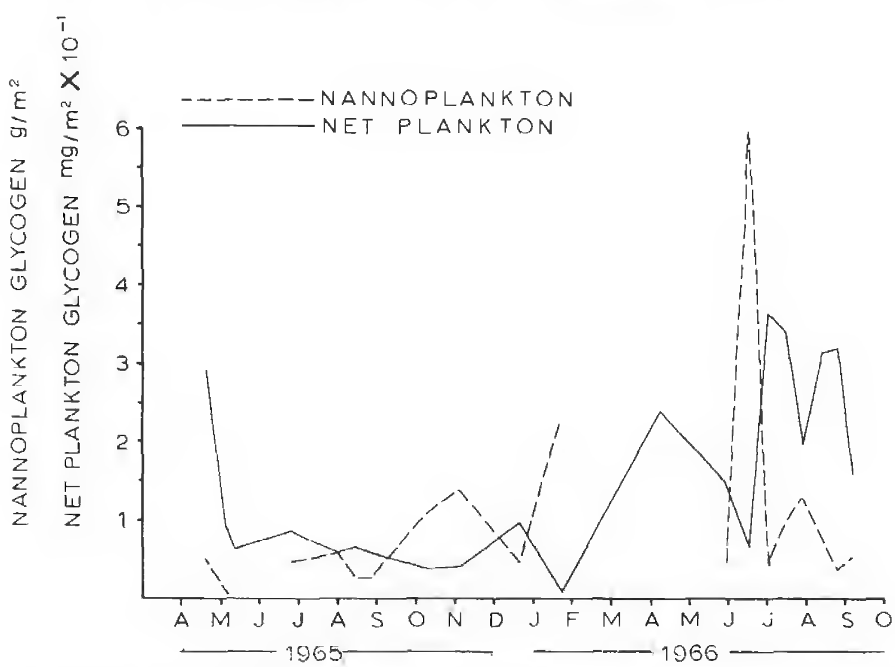

Figure 6. Seasonal variation in mean values of carbohydrate of net plankton and nannoplankton.

Nannoplankton mean carbohydrate content was 1.9 g/sq m, 5% of the dry weight, with a mean ratio of 1:1:18 for carbohydrate:protein:dry weight (Table 2). Carbohydrate and protein formed only about 10% of the dry weight, the low nutrient content in nannoplankton apparently resulting from large amounts of detritus and clay admixed with nannoplankton samples. Ash weight determinations on 15% of the samples gave values as high as 85% ash. Although nannoplankton showed a lower percentage nutrient content, on a unit area basis average carbohydrate level was a total of 235 times that of net plankton. Protein and carbohydrate maintained almost the same levels in the nannoplankton and showed similar seasonal fluctuations.

Lipid: The average net plankton lipid was 2.7% of the dry weight. The maximum, 16 mg/sq m, and minimum, 1 mg/sq m, values were observed in August and December, respectively, in 1965 (Fig. 7). In 1966, minimum, 1 mg/sq m, and maximum, 48 mg/sq m, occurred respectively, in January and August. From August 1965 onward, lipid values declined sharply to a minimum in winter and gradually increased with the onset of vernal conditions in 1966. The lipid content relative to the dry weight, during August lipid peaks, was 4.7% in 1965 and only 3% in 1966 when a considerably higher standing crop was noted (Table 1). Wimpenny (1938) reported similar results from the North Sea, and indicated that lipid content was lower when higher standing biomass was present. Fisher (1962) pointed out that size, spawning, maturity, and season affect lipid content of plankton, but he attributed the difference in lipid content to a differential in species composition from one year to the next. Lipid content in spring samples, which consisted predominantly of phytoplankton, was lower than in summer samples which included considerable zooplankton (Table 1). Blazka (1966) indicated that lipid content per unit biomass increases from algae to zooplankton in fresh water habitats. Possibly this is true in marine environments as well.

Nannoplankton samples were too small for routine determination of lipid content, but based upon a single cruise, when 18 gallons of net filtrate from each of the six stations were processed, lipid content was found to be 1.2% of nannoplankton dry weight.

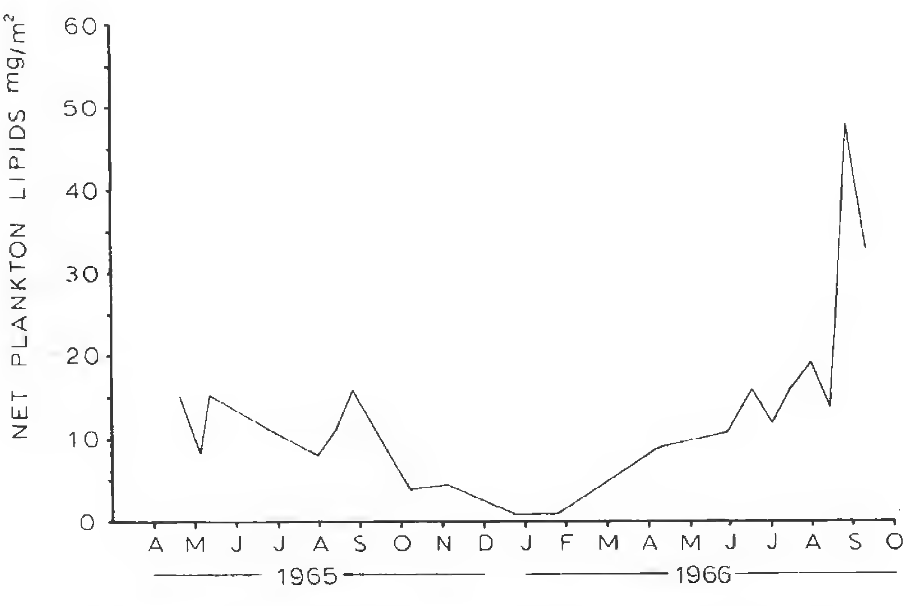

Figure 7. Seasonal variation in mean value of lipids of net plankton.

Figure 4 summarizes dry weight and nutrient composition data for net plankton and nannoplankton.

Caloric values and ash content: With one exception, net plankton caloric values, averaged for six stations on each date, fell within the range 3.6–5.4 kcal/ash-free g (Fig. 8). This is a remarkable consis-

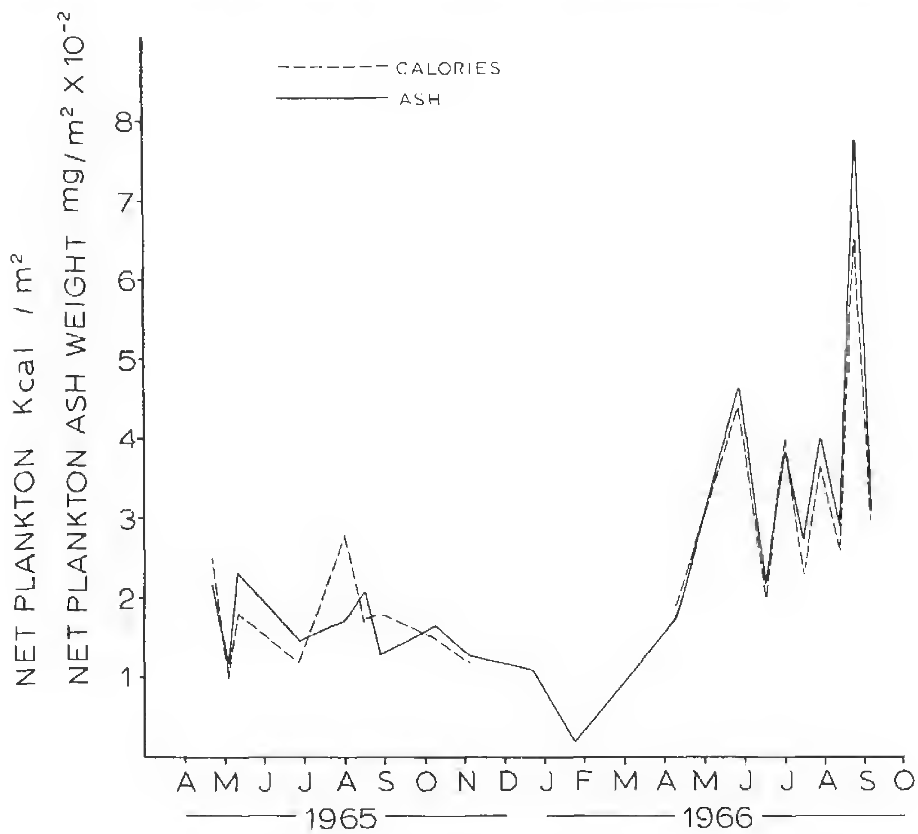

Figure 8. Seasonal variation in mean caloric values and ash weights of net plankton.

tency, considering that net plankton dry weights in the same sample series varied from 225 mg/sq m to 1560 mg/sq m. The mean value for the entire series was 4.85 kcal/ash-free g. Richman (1958) and Golley (1961) reported similar values for *Daphnia*, but caloric values obtained for Copepoda and Cladocera by Sitaramiah (1967) were as high as 7.02 kcal/ash-free g. Paine (1964) indicated that higher values are usually found for eggs and resting stages, although well-fed zooplankton also show a high caloric content periodically. The ex-

treme value found in the mixed net plankton samples in the present analyses was 9.9 kcal/ash-free g. This extremely high result derives from an anomalous datum from one station on one date, and may reflect a technical error.

The plankton samples yielded high ash contents throughout the period of study. Paine (1964) suggested that in organisms high in ash content, such as sponges and opisthobranchs, at least some low caloric estimates may result from difficulties in determining accurately the amount of noncombustible material present. Corrections for endothermic combustion reactions due to high ash content may be made as suggested by Paine (1966), but plankton samples may at times contain large amounts of low energy-yielding organic detritus, thus causing low estimates. The wet-ashing procedure employed in this investigation destroys carbonates and leads to low ash estimates, thus giving rise to slightly low results when caloric values per unit weight are computed on an ash-free basis.

Caloric content on a unit area basis followed a general trend similar to that shown by other parameters. Thus, the highest caloric value for 1965, 1.7 kcal/sq m on April 20, corresponded to the highest value for dry weight in 1965. In 1966, highest values for all parameters except carbohydrate corresponded to highest standing dry weight. Although caloric data for winter and early spring are not available, a trend towards decline in values was apparent after the peak in summer 1965. This may be associated with seasonal decrease in temperature. Vernal rise in caloric content was again noted in 1966, along with the rise in other parameters. The caloric value obtained in August 1966, 3.3 kcal/sq m, was the highest for the year. Other parameters in 1966 showed similar trends.

DISCUSSION

Nannoplankton, by definition, is that portion of the total plankton not obtained in tow-net collections. Since it is difficult to collect in quantity and even more difficult to study by classical, systematics–oriented methods, nannoplankton, historically, has been ignored to a large extent in favor of net plankton.

Nevertheless, various workers, approaching the assay of the total plankton from several standpoints, have all agreed that, at least in temperate and tropical waters, nannoplankton dominates the primary producer trophic level. Thus, Pomeroy and Johannes (1966) found that 94–99% of total plankton respiration resulted from organisms too small to be retained by a fine net; Banse (1964) estimated that nannoplankton made up more than half of the total plankton; and Yentsch and Ryther (1959) reported that, in Vineyard Sound, net plankton represented, in various samples, 2–47% of total plankton

biomass. The latter authors also tabulated other earlier results, including a report by Riley from Tortugas that net plankton amounted to only one percent of total plankton.

The study described here relates to observations on the total plankton crop of Mississippi Sound. Turbulent conditions are the rule in this body as in other Gulf Coast estuaries and lagoons, because of shallow waters, extensive wind stirring, river discharge from the mainland, and tidal mixing from the Gulf of Mexico through various passes between barrier islands. As a result, clay particles and detritus stay in suspension and become admixed with plankton samples, thereby giving rise to high ash values. Further, limited data indicate that, probably because of fine clays, ash is differentially increased in the nannoplankton fraction.

Despite this, nannoplankton, on a unit-area, total–water–column basis shows a total organic content greater by orders of magnitude than net plankton organic content. Thus, for an 18–month period in 1965 and 1966, mean nutritional composition of net plankton was 136 mg/sq m protein, as albumin, 15 mg/sq m carbohydrate, as glycogen, and 14 mg/sq m lipid, as triolein. During the same period, nannoplankton samples from the same stations and times showed means of 2.0 g/sq m protein and 1.9 g/sq m carbohydrate. These values were associated with mean dry weights of 504 mg/sq m for net plankton and 36.2 g/sq m for nannoplankton, including ash contents of 49% for net plankton and, based on very limited samples, 65% for nannoplankton.

The net plankton nutritional values amount, on a dry weight basis, to 27% protein, 3% carbohydrate, and 3% lipid. These levels are considerably lower than published results based on clay-free samples or individual species (Parsons, Stephens and Strickland 1961, Linford 1965, Raymont and Linford 1966, Blazka 1966). For nannoplankton, comparable data are not at hand. However, it has been pointed out by Gunter (1938, 1941, 1967) that most abundant species of fishes on the northern Gulf Coast feed at the base of the food chain. These are the menhaden, *Brevoortia patronus* and *B. gunteri*, the anchovy, *Anchoa mitchilli*, and the mullet, *Mugil cephalus*. Quite probably a considerable portion of their food is nannoplankton but there are no good data, although Peck (1894) said that menhaden filtered out dinoflagellates and minute plankton. There seems to be little doubt that oysters and other pelecypods feed to a considerable extent on nannoplankton (Nelson 1925, 1947) and filter feeding smaller crustaceans may also be in part based on nannoplankton.

No geographically uniform seasonal trend was found for nannoplankton standing crop, although net plankton did exhibit such a trend, a result in accord with the findings of Yentsch and Ryther (1959). Unfortunately, no method was available for estimating the

relative contribution of salt marsh detritus to the two plankton fractions. This detritus might either emphasize or mask a trend, since Odum and de la Cruz (1967) suggested that outpourings from Georgia salt marshes provided the major organic load in Georgia estuaries, and that the majority of this was "nanno detritus." Study on the yearly cycle of nannoplankton carbohydrate in Louisiana estuaries by Mulkana (1969), however, shows a normal seasonal trend associated with rise and decline of temperature.

Net plankton caloric values, on an ash-free weight basis, were consistent with various reported values in the literature. On the average, the caloric value of 1 g, ash-free, of net plankton was equivalent to 1.3 g glucose. On an area basis, caloric values were relatively steady. There was one extreme value of 3.3 kcal/sq m in August 1966, but the remainder fell in the range 0.5–2.2 kcal/sq m.

Nannoplankton samples were insufficient to permit caloric determinations, but should show larger values than net plankton per unit area consistent with the much larger standing crop of nannoplankton.

SUMMARY

1. On a unit area basis, mean nannoplankton dry weight was 72 times that of net plankton from April 1965 to September 1966 in Mississippi Sound.
2. The mean net plankton protein, carbohydrate and lipid were found to be 136 mg/sq m, 15 mg/sq m and 14 mg/sq m, respectively. The mean nannoplankton protein and carbohydrate were, respectively, 2.0 g/sq m and 1.9 g/sq m.
3. Mean levels of net plankton protein, carbohydrate and lipid were 27, 3, and 2.8%, respectively, of net plankton dry weight. In nannoplankton, protein and carbohydrate were 5.5 and 5%, respectively, relative to dry weight.
4. Although nutrient levels were higher in net plankton on unit weight basis, total nutrients available from nannoplankton were substantially higher. The mean nannoplankton–to–net plankton protein and carbohydrate ratios per unit water column were 24:1 and 235:1, respectively.
5. Some seasonal trends were apparent as changes in the standing biomass of net plankton, associated with temperature rhythm. Nannoplankton exhibited no definite seasonal trends. Present results suggest that factors other than temperature, such as grazing activity of herbivores and detritus influx, strongly influence nannoplankton dry weight.
6. Caloric values of net plankton showed seasonal trends similar to

those shown by dry weight. Average net plankton caloric value during the study period was 1.3 kcal/sq m.

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